USA 21

AMERICAN JOURNAL OF ALTERNATIVE AGRICULTURE

CAB INTERNATIONAL
00255901

Volume 11, Number 4, 1996

Alternative Agriculture News

A monthly newsletter available from Henry A. Wallace Institute for Alternative Agriculture

Noted for its succinct yet comprehensive coverage, **Alternative Agriculture News** reports on action by all alternative agriculture groups. It covers:

- Universities and government agencies.
- Non-profit organizations.
- Industry.
- Environmental and farm groups.
- Consumer organizations.
- Private/public sector cooperative efforts.

By reading **Alternative Agriculture News**, you will be well informaed about all of the major developments and trends in alternative agriculture.

HERE'S HOW TO SUBSCRIBE:

Rates for INDIVIDUAL Subscribers:

Alternative Agriculture News:
(12 issues)

$16 - U.S.
$21 - Canada & Mexico
$22 - Other Countries

American Journal of Alternative Agriculture:
(4 issues)

$24 - U.S.
$27 - Canada & Mexico
$28 - Other Countries

Combination Subscription:
Journal & Newsletter

$35 - U.S.
$43 - Canada & Mexico
$45 - Other Countries

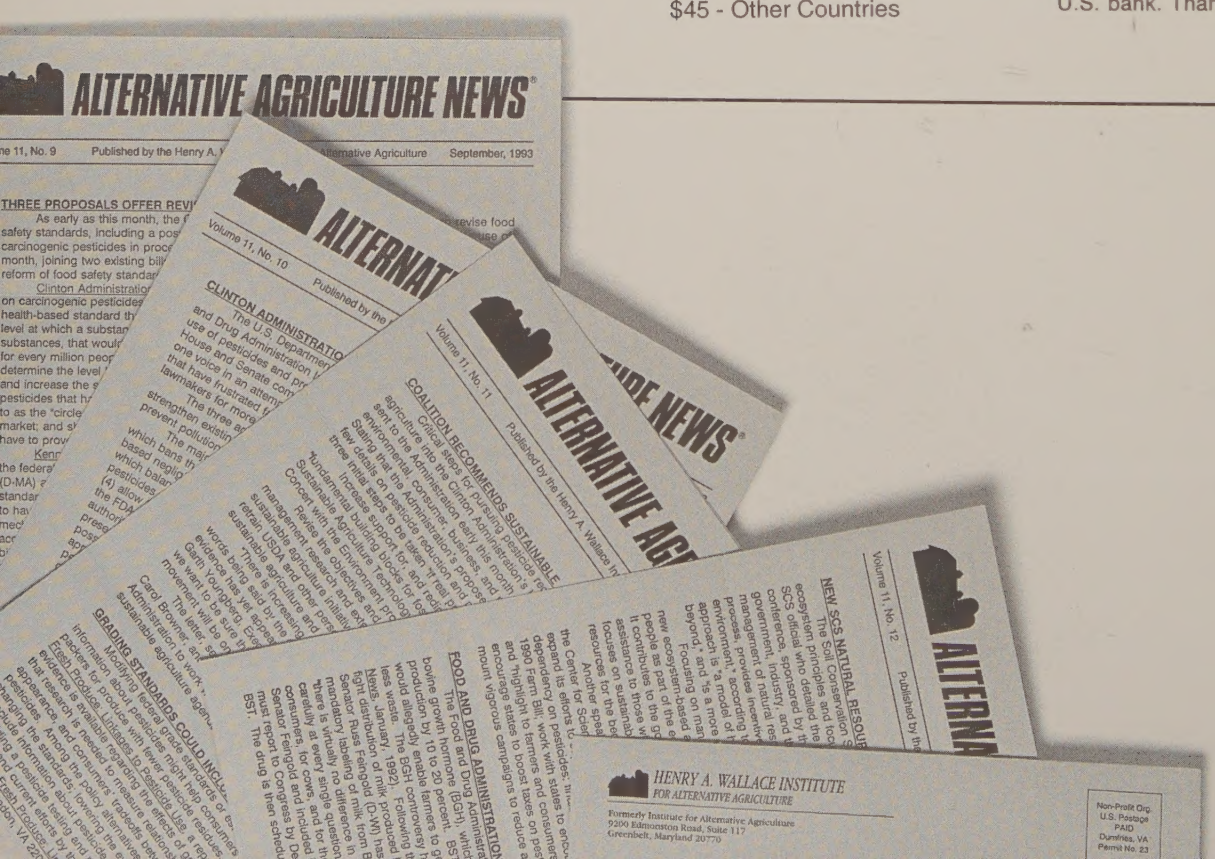
NOTE: ½ price for students with copy of student I.D.

Rates for LIBRARY subscriptions:

$44 - U.S.
$52 - Canada & Mexico
$54 - Other Countries

Please send a check payable to the:
Wallace Institute
9200 Edmonston Road, Suite 117
Greenbelt, Maryland 20770-1551

Outside USA:
Please pay with postal money order or check drawn on a U.S. bank. Thank You!



CAB INTERNATIONAL
Library Service
16 SEP 1997

AMERICAN JOURNAL OF ALTERNATIVE AGRICULTURE®

1996
Volume 11, Number 4

TABLE OF CONTENTS

Articles

138 **Abstracts from the Conference on Environmental Enhancement through Agriculture**

155 **Managing vertebrates in cover crops: A first study** • K. Shawn Smallwood

161 **The linkage between pesticide use and pesticide residues** • Fred Kuchler, Ram Chandran, and Katherine Ralston

168 **Substainable agriculture in the Corn Belt: Production-side progress and demand-side constraints** • David R. Lighthall

176 **Inoculative release of anecic earthworms in a California orchard** • Matthew R. Werner

182 **Green manure as a nitrogen source for wheat in the southeastern United States** • Julia B. Nelson and Larry D. King

Departments

Resources—175 • Upcoming Events—175 • Institute News—189 • Book Reviews—190

Journal Editorial Board

Miguel A. Altieri, University of California at Berkeley • Molly D. Anderson, Tufts University • Lloyd A. Andres, USDA-ARS • David F. Bezdicek, Washington State University • Harold F. Breimyer, University of Missouri • Michael C. Brumm, University of Nebraska • Frederick H. Buttel, University of Wisconsin • Katherine L. Clancy, Syracuse University • Eliot Coleman, Harborside, Maine • Kenneth A. Cook, Center for Resource Economics, Washington, DC • R. James Cook, USDA-ARS • John W. Doran, USDA-ARS • Sara Ebenreck, St. Mary's College • Thomas C. Edens, Michigan State University • Frank P. Eggert, University of Maine • Lloyd F. Elliott, USDA-ARS • A. Dale Flowerday, Pioneer Hi-Bred International • Charles A. Francis, University of Nebraska • Stephen R. Gliessman, University of California at Santa Cruz • Joan Gussow, Columbia University • Don F. Hadwiger, Iowa State University • Richard R. Harwood, Michigan State University • Glenn A. Helmers, University of Nebraska • Sharon B. Hornick, International Nature Farming Research Center, Bellingham, Washington • Larry D. King, North Carolina State University • Dietrich Knorr, University of Delaware • J. Patrick Madden, World Sustainable Agriculture Association • Robert H. Miller, University of Rhode Island • Robert I. Papendick, USDA-ARS • James F. Parr, International Nature Farming Research Center, Bellingham, Washington • Richard L. Ridgway, USDA-ARS • Douglas L. Young, Washington State University • Raymond R. Weil, University of Maryland

Wallace Institute Board of Directors

Dr. Anne K. Vidaver, President, Lincoln, Nebraska • Mrs. Jean Wallace Douglas, Honorary President, Washington, DC • Dr. Frederick L. Kirschenmann, Vice President, Windsor, North Dakota • Dr. Frederick R. Magdoff, Secretary, Burlington, Vermont • Dr. Cornelia Butler Flora, Treasurer, Ames, Iowa • Dr. Neil V. Anderson, Manhattan, Kansas • Dr. Jill Shore Auburn, Davis, California • Dr. David F. Bezdicek, Pullman, Washington • Mr. Michael Heller, Upper Marlboro, Maryland • Mr. Jose J. Montenegro, Salinas, California • Ms. Christine A. (Cass) Peterson, Warfordsburg, Pennsylvania • Mr. James H. Stephenson, Upper Marlboro, Maryland • Mr. Thomas N. Urban, Boston, Massachusetts • Mr. Gregory C. Watson, Falmouth, Massachusetts.

Journal Staff

Editor in Chief — *Garth Youngberg*
Editor — *William Lockeretz*
Associate Technical Editors — *Neill Schaller*
— *Marion E. Simpson*
— *David E. Ervin*
Book Review Editors — *Thomas C. Edens*
— *James F. Parr*
Assistant to the Editor in Chief — *Sarah C. Byler*
Circulation — *Joanna L. Hildebrand*
— *Nancy L. Ward*
Art Director — *Randy White*

The *American Journal of Alternative Agriculture* (ISSN 0889-1893) is published quarterly by the Henry A. Wallace Institute for Alternative Agriculture, Inc., 9200 Edmonston Road, Suite 117, Greenbelt, Maryland 20770-1551, in collaboration with the Center for Agriculture, Food and Environment, School of Nutrition Science and Policy, Tufts University, Medford, Massachusetts 02155. Neither the Wallace Institute nor Tufts University is responsible for statements and opinions expressed by authors.

Subscription Information

Annual Journal subscription rates: Library $44—US; $52—Canada and Mexico; $54—all other countries. Individuals $24—US; $27—Canada and Mexico; $28—all other countries. Students $12—US; $13.50—Canada and Mexico; $14—all other countries. Second Class postage paid at Greenbelt, MD. Postmaster: Send address changes to *American Journal of Alternative Agriculture*, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

Wallace Institute Information

The Henry A. Wallace Institute for Alternative Agriculture is a nonprofit, tax-exempt research and education organization established in 1983 to encourage and facilitate the adoption of cost-effective, resource-conserving and environmentally-sound farming methods. It works closely with producer groups, public research and education institutions, and government agencies in promoting a sustainable agriculture system.

Its programs include providing a national information clearinghouse, serving as a voice for sustainable agriculture in Washington, and developing and implementing research and educational outreach programs. It holds an annual scientific symposium and publishes a monthly newsletter.

The Institute is governed by a grass roots Board of Directors, which includes several commercial-scale organic farmers, and maintains a small professional staff. It is supported by memberships and donations and grants from foundations, corporations, and individuals.

Cover Photo

An almond orchard in Merced County, California, with an "insectary mix" cover crop. Photo provided by Shawn Smallwood, Consulting in the Public Interest.

Abstracts from the Conference on Environmental Enhancement through Agriculture

In November 1995 a conference on the theme "Environmental Enhancement through Agriculture" explored ways in which agriculture can improve the environment, not merely reduce the damage agriculture inflicts on it. The conference was organized by Tufts University, the American Farmland Trust, and the Wallace Institute for Alternative Agriculture. The conference took place in Boston, Massachusetts and it dealt with a wide range of what might be called "environmental services," such as providing habitat for endangered species, recycling wastes from nonagricultural sources, and producing alternatives to fossil fuels.

The program included 51 contributed papers, abstracts of which are reprinted here. The 36 papers marked with * are included in a proceedings volume. The proceedings (334 pp., softbound) is available for $20 (postage included). Prepaid orders, payable to "Trustees of Tufts College," should be sent to: Center for Agriculture, Food and Environment, School of Nutrition Science and Policy, Tufts University, Medford, MA 02155.

William Lockeretz

Watershed Protection

***Watershed Protection: A Better Way.** *Richard I. Coombe. Watershed Agricultural Council, RR 1, Box 74, NYS Route 10, Walton, NY 13856-9751.*

The program of the Watershed Agricultural Council for New York City's watersheds involves a new and better way to protect America's rural surface and ground water supplies. It is based on maintaining a well-managed agriculture as part of a comprehensive watershed protection program. The high quality of the water yielded by the Catskill and Delaware System watersheds, which is sufficient to meet federal criteria for avoiding filtration, is supported by the current low intensity land uses and land management patterns, including agriculture.

A Whole Farm Plan is the Program's main means for partnership between an individual farmer, whose involvement is voluntary, and the City. Each such plan is tailored to fit the site and the farm business. Specific farming practices to meet strict drinking water quality criteria are based on sound science and cover animal pathogens, sediment, nutrients, pesticides, and other substances with direct or indirect human health effects.

The Program's governing body and policy maker is the Watershed Agricultural Council, a not-for-profit corporation consisting of farmer and agribusiness leaders, the Commissioner of the New York City Department of Environmental Protection, and advisory members from government and private organizations.

The Program is based on the belief that farming is a preferred land use with significant long-term environmental benefits, as opposed to subdivision on the rural-urban fringe. It hopes to become a national model for watershed protection based on local decisionmaking, scientific evidence, and shared responsibility.

***The Watershed Approach to Integrating Agricultural Production and Water Quality Enhancement.** *Maurice G. Cook and J. Mark Rice. Department of Soil Science, Box 7619, North Carolina State University, Raleigh, NC 27607.*

A system of agricultural best management practices (BMPs) was implemented on a 2,100 hectare watershed in Duplin County, North Carolina to improve water quality. The BMPs included: nutrient, pest, and animal waste management; and soil conservation practices. Both surface and ground water were continually analyzed to assess the water quality impacts.

Nutrient management plans have been developed for over 80% of the cropland. Pest management plans have been developed for over 60% of the cropland. Over one-half of all plans have been implemented. Poultry mortality composting and improved swine waste management have decreased the potential adverse effects of animal operations. A constructed wetland shows promise for pre-treatment of swine waste before land application.

Stream monitoring shows decreasing amounts of nitrate- and ammonium-N in the surface waters of the watershed. Ground water monitoring shows relatively high concentrations of nitrate in areas of intensive swine and poultry operations. Ground water monitoring of pesticides reveals low levels of alachlor, atrazine, and metolachlor even though large amounts of these chemicals are used on crops.

The successful implementation of agricultural BMPs appears to be improving water quality. Both stream and ground water monitoring will be continued for several years to assess the changes in water quality more definitively.

Farmer participation in project planning and execution has contributed greatly to the project's success. The project has heightened citizens' awareness of water quality issues and has promoted producer adoption of BMPs.

***Padilla Bay Proposes a Unique Community Partnership for On-Farm Agriculture and Estuary Research and Education.** *Colette DePhelps. Center for Sustaining Agriculture and Natural Resources, Washington State University, Pullman, WA 99164-6240.*

In April 1993, the Washington State Department of Ecology, state administrator of the Padilla Bay National Estuarine

Research Reserve, partnered with Washington State University's College of Agriculture and Home Economics for three purposes: to identify and evaluate the primary environmental issues associated with the interface between farming systems and adjacent estuarine or other public receiving waters; to develop and evaluate problem-solving strategies related to these issues; and to propose educational strategies for use with the public and the agriculture community.

Outcomes of the partnership include the development of a Padilla Bay on-farm research and education program and a strategy for forming collaborative partnerships among diverse community interest groups, such as farmers and environmentalists, to identify, design, implement, and evaluate potential on-farm research and education activities. The participatory research and education strategy developed was built on the premise that the educational process is multi-directional. Not only do project participants learn from professionals, but professionals learn from project participants. The strength of the strategy lies in the development of a working coalition that energizes the creative forces of a wide range of community members to devise research and education activities that address agriculture/estuary issues of local concern and whose results will be locally acceptable and applicable.

***Operation Future: Farmers Protecting Darby Creek and the Bottom Line.** *Dennis W. Hall. Ohio State University Extension and Operation Future, 246 W. Fifth St., Marysville, OH 43040.*

Farmers along Big Darby Creek might have reacted negatively to the many outside interests in their agricultural community. Within just a few years, Big Darby had been declared a State Scenic River by the Ohio Department of Natural Resources, a Hydrologic Unit Area by the USDA, and one of twelve "Last Great Places" in the western hemisphere by The Nature Conservancy.

Admirably, Big Darby Creek farmers chose a different strategy. With the assistance of local Extension agents, farmers came together to form Operation Future, a nonprofit association with the mission of linking economic and environmental soundness to enhance the quality of life in the watershed. A positive sense of cooperation emerged when Operation Future farmers canoed Big Darby Creek with stream protection advocates to learn why the creek was so highly prized. Seeing many of the stream's 86 species of fish and 40 species of mussels was impressive, but the most valuable lesson was to recognize that two potentially adversarial groups, farmers and environmentalists, had more similar interests than first assumed.

Funded by the Kellogg Foundation, Operation Future has conducted a variety of watershed activities. The original canoe trip has been repeated nine times with over 300 different individuals participating. A "Farm of the Future" field day, conducted with Monsanto, drew 400 individuals. Recent annual meetings featured a prominent speaker and sold over 450 tickets.

As one of forty organizations in the Darby Partners, Operation Future has helped to advance a positive campaign that has become a national model for cooperation in ecosystem protection.

***Sustainable Farming Practices Benefit Minnesota Landscape.** *Dana Jackson and George Boody. Land Stewardship Project, White Bear Lake, MN 55110.*

Minnesota's rural landscapes are dominated by large fields of one crop, mostly corn or soybeans. Conservationists work to preserve remnants of the original landscape and scenic areas but assume that land in agriculture offers few environmental benefits.

The Land Stewardship Project (LSP) is a Minnesota non-profit membership organization that fosters a renewed ethic of farmland stewardship and promotes sustainable agriculture. LSP works with farmers who are developing an ecosystem relationship between agriculture and the natural world. They understand that their land is part of a larger whole, and their practices, unlike those of conventional agriculture, protect the soil and water and encourage the presence of wild species of plants and animals.

Two major influences lead farmers to establish sustainable practices that enhance the environment. Holistic Resource Management™ (HRM), is a decision making process that teaches farm families to work with neighbors and relatives to set a three-part goal that includes a vision of how they want the landscape to look far into the future. Under HRM, they also consider the effects of their farming upon culture and society. Management intensive grazing (MIG) is a method of grazing animals intensively for a short time in one area and then moving them to another area. Farmers strive for a thick, diverse mixture of grass and legumes that nourishes livestock profitably while soaking up rainwater. Minnesota landscapes benefit when row crops to feed animals are replaced by grass-based farming.

LSP's Biological, Social and Financial Monitoring Project and its projects to protect the Minnesota River watershed support both HRM and MIG. These projects are based on collaborations with other organizations and government agencies. The first involves a team of 25 people developing a kit of indicators for farmers to use in monitoring the sustainability of their farms. The second involves two elements: Clean Up Our River Environment, a grassroots effort to educate citizens about pollution of the Minnesota River; and the Chippewa River Stewardship partnership, a collaboration among diverse entities to restore wetlands and decrease pollution of the Chippewa River, a tributary of the Minnesota. Community discussion and collaboration undergird successful efforts to farm sustainably and create opportunities to change agriculture and enhance landscapes.

***Zuni River Watershed Act: An Ecosystem Plan.** *Gary Wooten and Ellen R. Dietrich. USDA Natural Resources Conservation Service, 6200 Jefferson Blvd. NE, Albuquerque, NM 87109.*

The Zuni River Watershed Act was passed by Congress in August 1992, with the purpose of authorizing formulation of "a plan for the management of natural and cultural resources . . . within the Zuni River watershed and upstream from the Zuni Indian Reservation." Potential watershed problems identified in the Act include severe erosion, reduced productivity of renewable resources, and reduced quality and quantity of surface water.

The Work Group, the decision-making group established for carrying out the intent of the Zuni River Watershed Act, is composed of the eight entities specified in the Act. This includes Tribes, Federal and state agencies, and private landowners. The

Work Group is assisted by a broadly representative Advisory Committee, and by ten technical teams, composed of experts in soils, range, forestry, wildlife, agriculture and cropland, hydrology and erosion, geographic information systems, archaeology, social and economic values, and cultural values. The link between the technical teams and the Work Group is a coordinator.

The final plan, due to Congress by September 30, 1997, must include a watershed survey describing current natural and cultural resource conditions, recommendations for watershed protection and rehabilitation on both public and private lands, management guidelines for maintaining and improving the natural and cultural resource conditions, and proposals for voluntary cooperative programs for plan implementation.

The Technical Teams have developed data collection methods that will be used by an interdisciplinary inventory team at sampling locations selected in each of the five subwatersheds. The sampling locations were selected using a stratified random sampling approach based on the distribution of land cover, slope, aspect, and soils within each subwatershed. The inventory will provide these teams with information on the current condition of the natural resources and will enable them to determine the types of problems that exist in different parts of the project area.

The Cultural Values and the Social and Economic Technical Teams will meet with the people in the watershed to identify the concerns and values that might affect how the project recommendations are accepted.

***Buffalo River Tributaries Watershed Project.** *Dennis D. Hackbart. USDA Natural Resources Conservation Service, Room 5404, Federal Office Bldg., 700 W. Capitol Ave., Little Rock, AR 72201.*

The Buffalo River Tributaries Watershed Project demonstrates that application of watershed protection and water quality enhancement practices can simultaneously support agricultural activity. The Buffalo River, designated the first national river in 1972, is a free flowing stream that meanders through the beautiful Ozark Mountains. The 150-mile river draws about one million visitors annually to participate in canoeing, camping, fishing, picnicking, and related activities. Unfortunately, this nearly pristine stream is threatened by an increase in bacteria stemming from the livestock industry, a classic example of conflict between economic and environmental concerns.

The good news is that a coalition of livestock producers, conservation districts, environmental activists, and State and Federal agencies have developed a "win-win" strategy that will enhance the water quality of the Buffalo River by reducing bacterial counts while increasing incomes of the livestock producers. The strategy involves the planning and implementation of a project funded under Public Law 83-566, the Small Watershed Act. The project includes about 230,000 acres of forest and grassland. This land supports dairy and beef cattle production and drains into the Buffalo River.

The project's dual approval plan calls for Federal cost-sharing with landowners who install animal waste and grassland management systems and streambank erosion control measures, and with local conservation districts for acquisition of conservation easements to protect riparian grasslands and forest lands. Project participation will be voluntary. Expected results of project implementation include significant reductions in bacterial counts in the Buffalo River, an increase in agricultural incomes from improved pasture production, and reduction of livestock losses from waterborne diseases.

***Marin Coastal Watershed Enhancement Project: A Cooperative Approach to Adapting Nonpoint-Source Pollution Guidelines to Local Conditions.** *Ellen Rilla[1] and Stephanie Larson.[2]*

[1]University of California Cooperative Extension, 1682 Novato Blvd., Novato, CA 94947; [2]University of California Cooperative Extension, 2604 Ventura Avenue, Santa Rosa, CA 95403.

Coastal nonpoint source pollution (NPS) concerns led to the design and implementation of the Marin Coastal Watershed Enhancement Project to improve water quality, fish habitat, and natural resources in three western Marin County coastal watersheds in California through voluntary adoption of appropriate rangeland management practices developed cooperatively. Specific objectives of the project include helping landowners identify water quality problems, demonstrating existing examples of good management, providing information on management practices that maintain or enhance water quality, assisting with monitoring programs, and providing technical assistance requested by landowners.

An important aspect of this project, which is ongoing, is the cooperative effort of local government support agencies working together in a "team" approach to assist landowners, and the organization of an advisory oversight committee made up of local community members, agriculturists, regulatory and support agencies and environmental organizations. All meetings are facilitated and recorded, with group agreement reached at each step.

Project products include the development of easy to read fact sheets, a creek care guide for rural landowners, a "how-to" ranch planning workbook and video on developing a ranch conservation plan, and an accompanying report assessing watershed condition and recommending future watershed enhancement projects. Pre-project interviews of the 30 members of the advisory committee indicated that success hinged on acceptance and buy-in from landowners. Follow-up interviews 18 months later indicated that both agency staff members and landowners have become more aware of NPS and what needs to be done. Both groups also mentioned that just coming together and building consensus was an important accomplishment of the project.

Benefits derived from a coordinated watershed approach include support agencies working together rather than at odds, landowners taking control of how they will respond to NPS regulations in a coordinated fashion rather than alone, and ultimately an enhanced watershed area.

Wildlife Conservation and Biodiversity

***Collaborative Problem Solving in Cameron County, Texas: The Coexistence Committee.** *Duane Dale,[1] Amy Purvis,[2] Terry Lockamy,[3] and Steve Thompson.[4]*

[1]DFD Associates, 764 South East Street, Amherst, MA 01002; [2]Department of Agricultural Economics, Texas A&M University, College Station, TX 77843-2124; [3]Texas Agricultural Extension Service, San Benito, TX 78586; [4]U.S. Fish and Wildlife Service, Laguna Atascosa Wildlife Refuge, Rio Hondo, TX 78583.

In an effort to protect an endangered falcon that was being released in a south Texas wildlife refuge, EPA proposed a one-county ban of all pesticides used in cotton production. This occurred in 1987, shortly after revisions to the jeopardy clause of the Endangered Species Act broadened the agency's power. Agricultural interests resorted to traditional lobbying activities and the draft proposal was withdrawn.

Facing the likelihood of a revised EPA regulation, cotton growers organized the Cameron County Agricultural and Wildlife Coexistence Committee, recruited environmentalists and wildlife managers as participants, and obtained legitimation as an ad hoc function of county government.

The committee developed its own plan for protecting the endangered falcon without totally eliminating cotton pesticides. To do so, they pooled their knowledge of the bird, of cotton production, and of pesticides, a significant step in itself given the mistrust in which environmental and agricultural interests typically hold each other. They also worked together to identify pesticides that were not in use, those used in doses determined to be no risk, and those determined to be safe to the bird if restricted to in-soil application. The U.S. EPA and the Fish and Wildlife Service were slow to respond to the committee's recommendations, but because of the members' persistence, the EPA eventually reversed the ruling that the 17 cotton pesticides jeopardized the falcon.

The most significant innovation in this case was to address pesticide regulation and endangered species protection through a collaborative local dialogue. Several elements contributed to an outcome that the participants considered positive: diversity of membership, legitimation from external authorities, a shared purpose, a flexible process, a thoughtful reframing of the problem, attention to mutual trust, anticipation of the consequences of their proposals, and development of "learning loops" as the committee monitored the impact of their recommendations. The process has been emulated within Texas and beyond, with varying degrees of success.

Point Remove Wetlands Reclamation and Irrigation Project, Conway and Pope Counties, Arkansas. *Robert G. Price. USDA Natural Resources Conservation Service, Room 5404, Federal Office Bldg., Little Rock, AR 72201.*

The Point Remove Wetlands Reclamation and Irrigation Project consists of 43,100 acres in Pope and Conway Counties, Arkansas, located 50 miles northwest of Little Rock. The Arkansas Game and Fish Commission's (AG&FC) Ed Gordon/Point Remove Wildlife Management Area (WMA) occupies 8,500 acres of the project area.

The Point Remove Wetlands Reclamation and Irrigation District, AG&FC, and the Pope and Conway County Conservation Districts have joined to address the project area's resource problems. The major problem is the lack of a dependable water supply to provide for winter waterfowl management on the WMA and fully irrigate potentially irrigable cropland.

The project would divert water from the Arkansas River into a system of canals, streams, and pipelines to deliver irrigation water in the summer and wildlife water in the fall. Individual cooperators would provide their own farm diversion systems for removing water from the project delivery network. Irrigated land would increase from approximately 4,600 acres to 12,600 acres.

A water-level control structure on the WMA would create approximately 6,000 acres of wetland habitat for migratory and resident waterfowl, fur bearers, wading birds, and other game and nongame species of wildlife. Taintor gates will provide the capability for moist soil management, greentree reservoirs, and resting and feeding areas for waterfowl.

Wetland/Cropland Rotational Management for Improved Wetland and Sustained Agricultural Production in the Tulelake Basin. *Carol Shennan. Department of Vegetable Crops, University of California, Davis, CA 95616.*

Tulelake is a high mountain valley on the California-Oregon border with 44,000 acres of irrigated agriculture next to the 13,000 acre Tulelake National Wildlife Refuge. The refuge is a critical part of the Pacific Flyway and with Lower Klamath Refuge supports one million migrating waterfowl, waterfowl production of 40,000 per year, and habitat for 411 wildlife species. Concerns facing the basin include degeneration of wetland habitat, declining fish and bird populations, hypereutrophication, pesticide use next to the refuge, and declining crop productivity from build-up of soilborne pests.

Wetland/cropland rotation cycles are being proposed as a management strategy to improve wetland habitat and reduce pest levels on agricultural land, and thus reduce pesticide use. A collaborative project was developed to test the feasibility of such schemes. The project's goals are: to establish effective mechanisms for participation of federal agencies, local farmers and concerned public groups in the research process; to test whether cover crops or short-term flooding can reduce soil pathogens, weeds and nematodes while providing desirable wildlife habitat; to establish farmer/refuge managed pilot study sites to test short and long-cycle wetland/cropland rotation schemes; to compare the ability of managed wetlands and croplands to remove nutrients and pollutants from agricultural drainage water; and to quantify collectively the economic, ecological and social barriers and opportunities for implementing alternative management options.

Outcomes from the initial stages of the project will be used to illustrate the effectiveness of approaches to establish farmer involvement and agency collaboration in the research program, and to illustrate issues that arise from working in a volatile political context.

***Valley Care: Bringing Conservation and Agriculture Together in California's Central Valley.** *Jack M. Payne,[1] Michael A. Bias,[1] and Richard G. Kempka.[2]*

[1]Ducks Unlimited, Inc., 9823 Old Winery Place, Suite 16, Sacramento, CA 95827; [2]Pacific Meridian Resources, 9823 Old Winery Place, Sacramento, CA 95827.

Valley Care is Ducks Unlimited's five-year comprehensive plan to expand its historical work on public wetlands in the Central Valley of California to private lands. Valley Care implements a major portion of the Central Valley Habitat Joint Venture's plan for waterfowl while directly benefitting neotropical migratory birds, threatened and endangered species, and other wildlife. Valley Care is finding ways to restore private wetlands as well as provide wildlife enhancement to private agricultural lands while continuing to add to the public wetlands base. This program is providing

education about wildlife to a broad range of the public and is establishing new partnerships among the agricultural community, businesses, public agencies, and environmental/conservation organizations.

Valley Care provides a large area of seasonally flooded wetlands (wildlife enhanced agricultural lands), improved management of existing habitats, permanently restored natural wetlands, riparian corridors and other habitats, and improved public understanding of the needs of wildlife in the Central Valley. The project directly benefits continental populations of neotropical migratory birds, migratory waterfowl and sandhill cranes, federal- and state-listed threatened and endangered species, and a host of resident wildlife and fish.

The primary goal of Valley Care is to change the way land is managed in the Central Valley. Valley Care demonstrates ecosystem management on a landscape scale. It serves as a prototype in that it is one of the first ecosystem-level efforts to be planned and carried out on this comprehensive scale. Ducks Unlimited is using this as a model to develop other landscape-scale projects throughout North America. At the end of the five-year program for Valley Care, Ducks Unlimited expects to have dramatically altered the cultural practices associated with rice farming and other agriculture in the Central Valley. We anticipate growers to winter-flood 200,000 acres of rice fields annually, with major benefits to wildlife, and expect 30,000 acres of farmland in the Sacramento-San Joaquin Delta to be flooded each winter for wildlife habitat. These 230,000 acres of seasonal habitat will be provided at no continuing cost to the public. Through a variety of programs, an additional 100,000 acres of habitat will directly benefit from improved management. We will have restored 12,500 acres of wetlands and riparian habitats, and a comprehensive wetlands education and communications program also will be in place.

The Valley Care program is taking advantage of satellite inventory and GIS technology to inventory enhancement and restoration projects and is targeting sites for future wetland restoration. Currently, a model is being developed that allows new wetland enhancement/restoration sites to be targeted. The model uses variables such as distance to wildlife refuges, distance to contiguous wetlands, distance to water delivery systems, waterfowl population densities, soils, and land ownership. These powerful and dynamic modelling tools will be used to monitor the success of the Valley Care program.

***Establishment of On-Farm Native Plant Vegetation Areas to Enhance Biodiversity Within Intensive Farming Systems of the Sacramento Valley.** *John H. Anderson,[1,2,3] Jennifer L. Anderson,[1] Richard R. Engel,[3,4] and Bruce J. Rominger.[3,5]*

[1]Hedgerow Farms, 21740 County Road 88, Winters, CA 95694; [2]University of California, Davis, Primate Center, Davis, CA 95616; [3]Yolo County Resource Conservation District, 221 W. Court Street Suite 8, Woodland, CA 95695; [4]California Foundation for Agriculture in the Classroom; [5]A.H. Rominger and Sons, 28686 Road 29A, Winters, CA 95694.

Intensive farming occupies the largest percentage of land in the Sacramento Valley of California. Intensive farming techniques, especially "clean farming" that maintains all noncrop areas without vegetation, have created farm ecosystems depleted or devoid of wildlife populations, including beneficial insects. We initiated a planting and outreach program that focused on restoring natural systems to non-cropped areas. Over the past 15 years we have tested suitability and establishment techniques for over 50 species of native plants from the local bioregion. Potential native plant vegetation areas common to most farms include roadsides, field borders, drainage ditches and sloughs, tail water ponds, equipment yards, and irrigation canals. Revegetation of these areas includes establishing a ground cover of native perennial grasses, sedges and rushes, and establishing native trees, shrubs, and vines matched to the type of habitat suited to the farm conditions.

Revegetation projects ongoing since 1981 clearly demonstrate improved and diverse wildlife populations on two participating farms. Additional benefits include control of noxious weeds, reduced soil erosion, enhanced water infiltration, and improved aesthetics. Negative impacts on farm production have been negligible.

The outreach programs have included over 12 formal workshops, invited lectures, farm publication articles, and numerous farm tours. Farmer interest and participation is increasing. Grant projects, including the Willow Slough Watershed Integrated Resource Management Plan, the Water Quality and Irrigation Ecosystem Management Program and the Total Resource Management and Outreach Program have recruited nearly twenty more growers to implement wildlife enhancement strategies and use their farms as outreach sites.

Fostering Biodiversity in Agricultural Systems: Integrating Landscape Ecology, Cultural Ecology and Community Participation. *Luis Malaret[1] and Dianne E. Rocheleau.[2]*

[1]New England Science Center, 222 Harrington Way, Worcester, MA 01604; [2]Clark University, Worcester, MA 01610.

Landscape pattern, a major determinant of biotic diversity and distribution, constitutes a critical nexus of human influence on biodiversity in agricultural mosaics. Complex agrarian landscapes include the interaction of humans with flora and fauna, at multiple scales of time and space, that defies analysis by traditional experimental approaches.

We focus on issues of design and methods in a landscape-level research project on biodiversity in a rural community in Kenya. This project examines the interaction between biodiversity and changing land use in current and historical contexts, promotes maintenance and possible increases in biodiversity, and assists human residents in the sustainable use of the resources. The study uses concepts and methods from population, landscape and cultural ecology, ecosystem analysis, and geographic information systems.

The project team consists of biologists and social scientists from the United States and Kenya in partnership with a rural community. The team did a preliminary survey of the biota in 1993 and conducted intensive interviews about environmental history at the extremes of an environmental gradient defined by the study site. The survey revealed distinct assemblages in the two areas: a total of 41 species of trees, 16 species of reptiles, 7 species of amphibians, and 17 species of termites, a surprisingly high diversity of study organisms considering the intensive human use and widespread land degradation.

The conclusion outlines strategies for building upon the preliminary data to structure participatory research and land use planning.

***The Delta Farmland and Wildlife Trust.** *David Melnychuk. British Columbia Ministry of Agriculture, Fisheries and Food, 1767 Angus Campbell Road, Abbotsford, British Columbia V3G 2M3, Canada.*

The Delta Farmland & Wildlife Trust (DF&WT) was established in 1993 as a non-profit organization dedicated to the preservation of farmland and the conservation of wildlife in the Fraser River Delta ecosystem of British Columbia.

The Fraser River Delta contains some of the most productive farmland in Canada as well as internationally significant wildlife values. Both of these important resources are under threat from urban expansion of the city of Vancouver and surrounding municipalities. In response to this threat, the community of farmers, conservationists, and concerned citizens have banded together in a constructive and cooperative manner and have created a new and exciting organization. Its prime mandate is to promote and encourage sustainable and stewardship practices that not only conserve but also enhance wildlife habitat.

The board of directors of this community-based organization includes representatives from the farming sector and from local conservation groups. In its brief history, the DF&WT has already had a positive impact on the farming/wildlife issue through several practical, on-the-ground initiatives. These initiatives can be categorized into two main groups: the first centers on demonstration of stewardship practices that sustain the agricultural resource and wildlife habitat, while the second concentrates on increasing public awareness and appreciation of the importance of farming and wildlife and the need for conserving both resources for the benefit of future generations.

Cooperation and respect between farmers and conservationists are essential for the survival of wildlife in the Fraser River Delta. The future success of the DF&WT is largely dependent on how well it can maintain and foster this relationship.

Wildlife Conservation as a Catalyst for Implementation of Sustainable Agricultural Practices in North Carolina. *Peter T. Bromley,[1] John R. Anderson, Jr.,[2] William E. Palmer,[1] and J. Theodore Morris.[3]*

[1]Department of Zoology, [2]Crop Science Department, and [3]Department of Forestry, North Carolina State University, Raleigh, NC 27695.

For agricultural producers and for environmentally concerned citizens, both rural and urban, wildlife conservation represents unique common ground. The bobwhite quail, an environmental barometer and symbol of the high quality of life in the southeastern U.S., has been declining for over 30 years. The demise of quail populations has alarmed sportsmen, landowners, and conservation agencies. Prominent among the hypotheses explaining the downward trend is habitat modification and intensive use of pesticides associated with post-World War II industrialization of southern agriculture. Over the past 3 years, we have employed radio-telemetry in replicated, whole farm studies as well as on-farm mesocosm experiments to measure the direct and indirect effects of modern foliar and granular pesticides on quail in realistic field scenarios, to assess the role of conservation tillage in the quail life cycle, and to evaluate the impact of habitat modifications, in the form of ditch bank and field border management, on quail numbers and behavior. Using unique methods like human-imprinted quail to quantify the quality of crop and noncropland habitats, we have demonstrated that management practices that conserve soil and water can be integrated to increase wildlife populations, particularly of quail, on commercial grain farms. The management systems that we have designed simultaneously improve crop production and enhance wildlife resources; they are economically compelling. Our work has generated regional support and unprecedented cooperation among numerous organizations with diverse interests. With farm wildlife as the catalyst, crop producers, global integrators of swine and poultry, agricultural agencies, regulatory agencies and wildlife conservation groups are helping expand our integrated farm and wildlife management ideas to a landscape scale.

***Birds of Prey and Their Use of Agricultural Fields.** *Kerry J. Fitzpatrick. Marine-Estuarine-Environmental Sciences Program, 0220 Symons Hall, University of Maryland, College Park, MD 20742.*

Agricultural fields are a viable habitat for grassland birds of prey. A review of the literature reveals several studies suggesting a management strategy to attract raptors to agricultural lands. These studies document the preference of birds of prey to forage over shorter vegetation, particularly grasses. The basis for this trend is thought to be an increased vulnerability of prey. In the Northeast, the dominant grassland prey is the meadow vole, *Microtus pennsylvanicus*. A balance is needed between providing enough vegetation to provide food and cover for a healthy vole population and having short enough vegetation to allow raptors to locate and capture prey more easily. Minor adjustments in standard field management practices could create the right conditions to meet both species' needs. Because the group of raptors using fields represents the largest portion of birds of prey, the management of agricultural fields offers the potential for significant habitat improvements. Specific land uses are examined where this strategy can be applied with little or no extra effort over standard practices. The agricultural benefits, benign aspects, and potential conflicts are discussed. The paper concludes with the direction of my study and other areas where more information is needed to use this approach.

***Value of Shade Coffee Plantations for Tropical Birds: Landscape and Vegetation Effects.** *Jeffrey David Parrish[1] and Lisa J. Petit.[2]*

[1]Department of Ecology and Evolutionary Biology, Box G-W, Brown University, Providence, RI 02912; [2]Smithsonian Migratory Bird Center, National Zoological Park, Washington, DC 20008.

With the imminent full conversion of the natural tropical landscape to an agricultural mosaic, tropical conservation requires a redirected effort toward alternatives offered by the agricultural ecosystems remaining after forests have disappeared. Coffee is one such alternative: it is a dominant feature in the economy and landscape of developing tropical countries that can even enhance tropical biodiversity. Grown under a shade canopy, coffee can provide critical habitat

for tropical forest organisms where no natural forest vegetation remains. However, since the early 1980s, coffee has undergone a conversion from shade-managed production to cultivation under full sun conditions with removal of most or all of the shade canopy. The loss of canopy trees in a "technified" plantation represents a concomitant loss in biodiversity of forest organisms. While traditional shade coffee plantations generally support biodiversity, they vary tremendously in habitat characteristics, placement in the tropical agricultural landscape, and the resulting abilities to harbor viable populations of many forest species. In this study we evaluated the individual and combined effects of several habitat characters and landscape-level factors on the species richness and abundance of tropical resident and migratory birds in shade coffee plantations of western Panama.

We measured bird abundances, community composition, and vegetation and landscape variables within 10 plantations at varying distances from contiguous forest. As canopy cover increased in a plantation, there was a concomitant increase in the abundance of forest-wintering migrants and in the number of migrant species within a plantation. This suggests that shadier sites more closely resemble a forest in vegetation structure or in available resources, and as a result can harbor a greater diversity and abundance of migratory birds. Migrant species tended to be more abundant in coffee plantations with higher densities of flowering canopy trees. As a plantation was located further from the contiguous forest, the number of forest species shared with both the local forest interior and the forest border decreased significantly, suggesting that shade coffee has maximum conservation value when used as a multi-use buffer zone habitat along the border of protected forest areas. As distance from riparian dispersal corridors increased, the number of forest species in a plantation also declined. Multiple regression models showed that landscape and habitat factors both were important in explaining bird abundance and species richness. When managed with these habitat- and landscape-level factors in consort, shade coffee plantations can provide a viable conservation tool in highly managed agricultural landscapes while meeting the needs of human economy.

Beyond Nature: Toward a Conceptual Framework that Allows for Environmental Enhancement through Agriculture. *Isidor F. Ruderfer. Conservation Ecology and Sustainable Development Program, Institute of Ecology, University of Georgia, Athens, GA 30602-2202.*

Before we can consider "environmental enhancement through agriculture," we must rethink what we mean by "environment" and "agriculture." Agriculture is treated antagonistically in most environmental discourse. I distinguish between two extremes in the popular discourse: preservationism and deep ecology. The former sees agriculture as a necessary evil whose impact can be lessened through intensifying technologies. The latter would rather see agriculture abandoned altogether.

At the root of this antagonism is something these two poles of environmentalism share: a concept of "nature" as a well-functioning and self-governing entity-unto-itself. Individual organisms temporarily occupy previously established nodes in this web of energy, nutrient, and information flows. According to preservationism, being human is completely incompatible with being a passive node in the system; to be human is to be self-determining, self-creating, and, therefore, inherently separate from and destructive of nature. According to deep ecology, however, we do have a given role within the system, but rather than accept that passive role (as have hunter-gatherers, holders of this perspective sometimes claim), we have opted for the comforts and conveniences of modernity and thereby have fundamentally upset the equilibrium of the system.

In their assessments of human activity, these poles of environmentalism are forced to come to terms with "indigenous" agriculture. Deep ecology tends to see humans who are inherently different from us living "in harmony with nature." Preservationism tends to see humans who are as destructive as any others, once low population densities are taken into account. Oddly enough, evidence appears to support both interpretations: evidence indicating that these peoples who, on one hand, appear to be in passive "harmony with nature" also are actively manipulating their environments.

If we can make coherent sense of this apparent paradox, we are on our way toward an environmentalism that has room for humanity and human action. My suggestion for resolving this apparent paradox is to get rid of the concept of "nature" as a self-contained thing-unto-itself. Rather than viewing organisms as temporary occupants of predefined roles in an already well defined web, perhaps we should view living beings as active entities that continuously and creatively develop their own roles. Thus, responsible environmental citizenship does not have to preclude active manipulation of the environment. As a result, agriculture would no longer need to be considered an environmental crime, but rather a particular mutualistic arrangement of organisms. The problem posed to us then by the necessarily interspecies ethics of such a post-'nature' would be: "How can we involve a greater variety of organisms in these and other mutualistic arrangements?"

Livestock Systems

***Environmental, Economic, and Social Benefits of Feeding Livestock on Well Managed Pasture.** *William Murphy,[1] Joshua Silman,[1] Lisa McCrory,[1] Sarah Flack,[1] Jon Winsten,[1] David Hoke,[1] Abdon Schmitt,[1] and Brian Pillsbury.[2]*

[1]Department of Plant and Soil Science, University of Vermont, Burlington, VT 05405; [2]USDA Natural Resources Conservation Service, 18 Blair Park Road, Williston, VT 05495.

A sustainable rural culture and its agriculture depend not only on fixing what is wrong with conventional agriculture in terms of soil erosion, pollution, and farm profitability but also on improving the farm family's quality of life and on revitalizing rural communities. One solution to the problems of farmers and rural communities lies in better use of permanent pasture. Feeding livestock on well-managed pasture can cost only one-sixth as much as feeding them in confinement. Also, it requires less labor, thereby improving farm profitability and family quality of life. As pasture-based farm profitability increases, farmers diversify their spending in ways that can result in more prosperous rural communities.

Using permanent pasture instead of tilled crops to feed livestock stops soil erosion, adds soil organic matter, and decreases

atmospheric carbon dioxide. About 48,000 kg of carbon dioxide can be removed from the atmosphere and the carbon sequestered in the soil in each hectare of land converted from tilled crops to permanent pasture. Is this a way of reducing the danger of global warming from atmospheric carbon dioxide?

Surface and ground water quality has been degraded especially by soil sediments and nitrogen, phosphorus, and pesticide runoff and leaching from tilled cropland. Farmers feeding livestock on intensively managed permanent pasture grow less corn, and other tilled crops, and require less fertilizer, pesticides, and phosphorus-containing feed supplements. These input reductions could benefit surface and ground water quality because less pollutants would enter and leave pasture-based farms.

The Pasture Management Outreach Program of the University of Vermont's Environmental Programs in Communities Project strives to help farmers learn how to use the pasture resource to its full potential to achieve these benefits. This program has helped increase the net income of more than 120 farms by as much as 350% and has saved farmers from bankruptcy. It also has resulted in farm children returning to dairy farming after they had rejected it as a career when it was being done in confinement.

The special beauty of all this is that no government incentive is needed to attract farmers to use this beneficial farming practice. Dramatically improved farm profitability and decreased labor demands that result from using well-managed pasture are the large, very attractive carrot.

***Integrated Resource Management at Work: A Case Study.** *Scott M. Barao. Department of Animal Sciences, University of Maryland, College Park, MD 20742.*

Integrated Resource Management (IRM) is an important tool for beef cattle producers who wish to operate an efficient, profitable and sustainable enterprise in today's competitive environment. IRM provides a whole farm focus and facilitates the optimum management of farm system resources.

A 4-year participatory on-farm project was initiated to demonstrate and apply the principles of IRM within an existing beef cow-calf enterprise. The goal of the project was to design and implement management practices that improve animal and farm system performance and profitability while protecting and enhancing the surrounding environment. General farm goals were set around the assumption that management practices that increase and enhance the grazable land base would also contribute positively to environmental stewardship and farm system sustainability.

The chosen producer-owner demonstration farm lies within the Piedmont region of northeast Maryland; is rolling in its terrain; includes a significant fraction of highly erodible, loam-based soil; and is within the Deer Creek Watershed, a tributary of the Susquehanna River leading into the Chesapeake Bay. Several spring-fed streams cross the farm along with one major creek. Annual rainfall totals approximately 45 inches.

Farm goals and whole farm management plans were established at the outset. Over the duration of the project, existing crop land (tilled) was converted to permanent pasture consisting of mixed stands of grass and legumes; existing pastures were renovated and improved through the no-till addition of up to 30% legumes; permanent and temporary fence systems were installed; and a year-round grazing plan was established. In addition, innovative animal watering systems were developed to allow full utilization of grazing land while minimizing animal impact on existing streams.

Significant accomplishments include:

- Improved animal nutrition and increased farm carrying capacity (dry matter yield).
- 80% reduction in nitrogen, phosphorous and herbicide application.
- Elimination of soil erosion and soil loss.
- Reduced and controlled animal access to streams.
- Improved animal waste management.
- 90-100 day increase in grazing season with significantly reduced use of harvested, stored feeds and confinement feeding.
- Improved wildlife habitat with 30% increase in observed deer numbers and 10-15% increase in fox counts.
- 53% increase in cow herd size.
- 40% reduction in yearly cost per cow.

Overall, this project successfully demonstrated the opportunity present within agriculture to attain optimum production levels, reduce costs and achieve farm goals within the context of whole system sustainability. The best management practices that were implemented through this IRM effort resulted in a positive economic and environmental return and made optimum use of an existing renewable resource.

***The Potential of Dairy Grazing to Protect Agricultural Land Uses and Environmental Quality in Rural and Urban Settings.** *Bryan T. Petrucci. American Farmland Trust, Center for Agriculture in the Environment, P.O. Box 987, DeKalb, IL 60115.*

Of all the new production systems that have emerged and are currently being tested, grass-based livestock systems may have the most potential to address the integrated environmental and social goals promoted by advocates of sustainable agriculture. However, the main benefit of grazing, and the primary reason that so many producers have already converted to grass-based production systems, is the potential for profits.

With this combination of environmental and economic benefits, grass-based livestock enterprises could be the answer to some of the most pressing economic and resource concerns facing rural America today, particularly in the dairy sector. Dairy grazing may be the way for small to medium-size dairy producers to remain competitive and profitable in the 21st century, especially on farms at the urban edge where conflicts with non-farm residents over environmental concerns are likely to occur. Win-win situations for both farmers and rural nonfarm residents could be created in communities willing to work cooperatively with dairy graziers.

***Enhancement of Communities with Pasture-based Dairy Production Systems.** *Steven P. Washburn,[1] René J. Knook,[1] James T. Green, Jr.,[2] Gregory D. Jennings,[3] Geoffrey A. Benson,[4] James C. Barker,[3] and Matthew H. Poore.[1]*

[1]Department of Animal Science, [2]Department of Crop Science, [3]Department of Biological and Agricultural Engineering, and [4]Department of Agricultural and Resource Economics, North Carolina State University, Raleigh, NC 27695.

A collective vision of seasonal, pasture-based dairy farms is being developed for North Carolina. Such dairies should ensure continued local supplies of fresh milk for a

growing population while providing economic, aesthetic, and social benefits for communities. Pasture-based dairies have lower feed costs, provide acceptable nutrient balance of nitrogen and phosphorus, and reduce concerns about odor, pollution, flies, noise, and use of fossil fuel. Seasonal, pasture-based dairies could lower stress and provide more variety and free time for farm workers. Provisions for economical land would allow such dairies to function compatibly in rural and suburban environments. Near larger urban areas, pasture-based dairies could seek long-term land leases within local park systems or special agricultural zones, thereby providing effective public green space. The aesthetic appearance of such farms would make farm vacation enterprises and tours for school children or civic clubs popular.

Profitable local family farms and the sense of community resulting from such cooperation should have lasting social and economic benefits. Differing soil types, climates, and economic conditions dictate the need for functional, local prototypes to demonstrate the feasibility of grazing-based dairies to farmers, lenders, and community leaders.

***Riparian Wetlands Then and Now: An Enhanced Environment Created by Agriculture.** *Quentin D. Skinner and Joseph G. Hiller. Cooperative Extension Service, Department of Rangeland Ecology and Watershed Management, University of Wyoming, Laramie, WY 82071.*

A historical account of hydrological conditions of the Rocky Mountain Region is used to describe streamside vegetation as observed by Lewis and Clark and other early explorers. We compare these presettlement conditions to riparian conditions that now exist to demonstrate what agriculture has accomplished to enhance the fishery, wildlife, and recreation resources of the Western U.S. We demonstrate that ranchers alone have enhanced riparian wetland systems and have developed off-stream water sources in such a way that they are now major elements in the proper control of nonpoint pollution from western rangeland. Because of land ownership patterns and permitted rights to water resources, maintaining the integrity of ranching operations is essential to insure continued existence of present fishery and wildlife resources of the West.

***Environmental and Economic Benefits of Organic Dairy Farming in Ontario.** *Yetunde O. Sholubi,[1] D. Peter Stonehouse,[1] and E. Ann Clark.[2]*

[1]Department of Agricultural Economics and [2]Department of Crop Science, University of Guelph, Guelph, Ontario N1G 2W1, Canada.

Societal concerns about the long-term viability of commercial livestock agriculture reflect growing dissatisfaction with prevailing methods of livestock production. Yet ruminant livestock are the foundation on which profitable and environmentally sustainable food production systems are based. Although the environmental benefits of perennial forages are widely acknowledged, profitable economic returns require that the forages be processed through livestock. Systems that depend less on conserved feeds and confinement and more on pasture and grazing management will reveal the environmental and aesthetic advantages of ruminant-based agriculture.

A survey of eight organic dairy farms in western Ontario illustrates both the crop and livestock husbandry practices and the potential profitability of dairies that emphasize environmentally beneficial methods of milk production. For example, soil erosion and degradation were minimized through year-round soil cover with winter cereals, catch crops and perennial forages. Choosing small grains instead of corn as a feedstuff enhanced weed control while eliminating the hazards of using biocides.

Rations emphasizing perennial forages and small grains, all grown without synthetic fertilizers or biocides, supported production levels equal to the provincial average. With comparable herd sizes, organic dairies posted net returns per cow, per hectare, and per unit of labor that exceeded those from conventional dairies. The findings of this preliminary study suggest that environmentally sound agriculture can be at least as profitable as the agriculture practiced under the prevailing paradigm.

***Can Sustainable Agriculture Landscapes Accommodate Corporate Agriculture?** *Dennis R. Keeney. Leopold Center for Sustainable Agriculture, Iowa State University, Ames, IA 50011.*

Livestock-based farming systems in the United States have rapidly moved toward the industrial model. A current example is the rapid growth in the past five years in large-scale swine confinement operations. These are characterized by dominance of outside capital and management, and by odor and pollution problems caused by concentration of swine in small areas. This development is causing concern because of the negative effects it may have on rural communities and landscapes. Promoters of large swine systems point out that the income and job potential, competitive pressures of a world economy, and economies of scale make this switch essential to retain the competitive power of local, state, regional and national economies.

The resulting debate has split the agricultural community at a time when it can ill afford to lose energy and influence by such divisive arguments. Instead, dialogue needs to be established and a fresh look should be taken of the issue. Can these types of systems fit into the landscape? Watershed planning could be the answer. Large confinement systems could be designed that fit the unique aspects of a watershed. Examples include siting to protect streams, staying clear of communities, and designing systems that can assimilate the wastes and control odors.

However, the development patterns in the affected rural landscapes are already set because of property ownership, access to utilities, etc. Thus more immediate measures must be taken so that development does not overwhelm the landscape. Measures are proposed that include grain and manure sharing and putting emphasis on developing competitive technologies so that operations of a wide range of sizes can exist together.

Waste Recycling and Nutrient Management

***On-Farm Composting of Food and Farm Wastes: Economic and Environmental Considerations.** *John M. Halstead,[1] Terri Emmer Cook,[2] and George O. Estes.[3]*

[1]Department of Resource Economics and Development, University of New Hampshire, Durham, NH 03824; [2]Vanasse Hangen Brustlin, Inc., Watertown, MA

02172;[3]Department of Plant Biology, University of New Hampshire, Durham, NH 03824.

Food waste, which comprises between 8 and 25% of the national waste stream, is a legitimate target for alternatives to the traditional waste management strategies of landfilling and conversion to energy. On-farm composting of source-separated food waste holds promise as an environmentally sound, economical alternative for waste management.

We examine whether on-farm composting can be a profitable alternative enterprise for farmers, and whether a high quality, valuable compost product can be made from source-separated fruit and vegetable waste and on-farm "waste" products, and we assess the level of technology necessary for on-farm composting. Using three case studies of on-farm composting projects in New Hampshire, cost estimates for compost production under various levels of technology are developed and analyses of compost quality resulting from different composting approaches are provided. In addition, we estimate the volume of waste generation necessary within a region to support a single on-farm composting enterprise. This research provides guidelines for deciding whether to purchase new equipment or use existing equipment for composting, for establishing tipping fees for waste generators, and for estimating the time necessary to collect, mix, and turn the compost, based on the volume of waste collected.

***Recycling Municipal Organic Wastes Through Compost Application to Agricultural Land.** *Thomas A. Obreza. Southwest Florida Research and Education Center, Institute of Food and Agricultural Sciences, University of Florida, P.O. Drawer 5127, Immokalee, FL 33934.*

Disposal of municipal solid waste (MSW) has become complex because of difficulties in siting new landfills. Florida's MSW production is steadily increasing with its population, so other environmentally acceptable disposal means need to be explored. Composting MSW and returning it to the land recycles organics back to the site where they originated.

The importance of organic matter to soil productivity, especially in Florida's sandy soils, has long been recognized. Adding a high rate of MSW compost improves soil physical, chemical, and biological properties. Compost can increase long-term soil quality because of its stability.

Composts made from household garbage feedstock were evaluated for effects on soil properties and vegetable crop yields. When added to sand at 112 t/ha, compost increased water-holding capacity about 6% by volume. When stable, mature composts were added to field soils at 27 to 112 t/ha, tomato, bell pepper, crookneck squash, and watermelon grew as well or better than crops in unamended soil. Yield increases were associated with increased water use efficiency and soil fertility. When immature composts were applied, plant growth was reduced by phytotoxicity. Unstable composts matured in the soil after about 90 days. Heavy metal uptake by watermelon was negligible from compost-amended soil.

Long-term positive compost effects on soil fertility included increases in soil pH, organic matter concentration, and soil-extractable P, K, Ca and Mg. Chemical analysis of composts showed high Ca and Fe concentrations, which may have increased retention of P fertilizer.

The main barriers for large-scale compost use by agriculture are production and transportation costs. There will be no incentive to produce compost if growers cannot afford to use it. If the urban community will subsidize the cost of compost distribution, then its use will become more attractive.

An Assessment of Composted and Uncomposted Animal Waste Using the Multiple Goals of Waste Recycling, Soil Restoration, and Water Quality Protection. *Susan S. Andrews[1] and Luanne Lohr.[2]*

[1]Institute of Ecology and [2]Department of Agricultural and Applied Economics, University of Georgia, Athens, GA 30302.

Demonstration of agricultural practices that provide environmental protection is a necessary step in the development of strategies for a sustainable environment. Although definitions vary, sustainable practices often entail methods for chemical input reductions, soil organic matter restoration, and conscious environmental protection. Nutrient recycling is key to sustainable agroecosystem management, making farm reuse of nutrients in animal wastes very attractive. Economic and environmental comparisons of composted and non-composted animal waste management can facilitate technology adoption to meet multiple objectives for environmental enhancement through agriculture.

The evaluation of alternative systems at various scales allows decision makers to choose the best management options for their specific situation. As a determination of ecological sustainability, this study compared composted broiler litter, non-composted broiler litter, and chemical fertilizer amendments on a vegetable crop. The results were used in comparative crop enterprise budgets to assess economic feasibility of several possible management scenarios. Finally, a thumbnail assessment method was developed for watershed level comparison of farm (crop) revenue, animal waste diversion, soil organic matter additions, and water quality risk.

Using organic matter in place of or coupled with chemical fertilizer can significantly reduce chemical usage and divert nutrients from the farm waste stream. However, the levels of nitrate-N and water-soluble P in compost pose a significant threat to surface and ground water quality. The public benefits of compost use appear greater than private economic objectives. Analyses of both on-farm and off-farm impacts should be included in the determination of feasibility, at least to the watershed scale, so that public costs and benefits can be assessed. It should be the end-users who make the final appraisal of management alternatives allowing for a tailored fit to specific needs. Taking a broader view of systems can assist in the development of win-win approaches to agriculture.

Use of Solid Waste Compost in Landscape Beautification. *Allen V. Barker, Tara A. O'Brien, Gordon Fletcher-Howell, and Jayaram Daliparthy. Department of Plant and Soil Sciences, University of Massachusetts, Amherst, MA 01003.*

The University of Massachusetts has developed a cropping system by which aesthetically appealing landscapes can be produced with wildflowers in composts. Nitrogen-rich composts made from municipal solid wastes, including biosolids, are applied as mulches in which the wildflowers are seeded. A weed-suppressing barrier mulch

of paper, sawdust, geotextiles or other permeable material is placed under the compost mulch. Newspaper is the recommended material. A one- to two-inch thick layer of compost supplies sufficient growing medium and nutrition to support plant growth with much lower fertilization than is required for conventional establishment of plantings without composts. The system can be adapted for small or large plantings in soils with a wide range of fertility. Use of leaf or yard waste compost requires fertilization to support crop growth. This system is recommended for city and park landscapes, roadsides, industrial landscapes, nurseries, home gardens, or any landscape in which a showy display of native flowering species is desired. The system promotes safe recycling of domestic wastes.

Combining Municipal Solid Waste Compost and Poultry Litter to Create a Slow-Release Organic Fertilizer and Reduce Off-Farm Nutrient Pollution. *Leslie R. Cooperband. Wye Research and Education Center, University of Maryland, Queenstown, MD 21658.*

Animal wastes, particularly from poultry operations, are significant contributors to agricultural non-point source pollution in the Chesapeake Bay region. Nonetheless, animal waste use for on-farm nutrient supply can be an essential aspect of sustainable farming systems. Crop and manure management practices that biologically and chemically immobilize the most soluble nutrient forms could minimize nutrient loss from agricultural fields. The Delmarva's proximity to large urban centers has sparked interest in recycling urban wastes like municipal solid waste (MSW) on agricultural land. However, MSW is composted without adding nitrogen and phosphorus; both are needed to mature the compost before crop application. The combination of MSW (essentially carbon) and poultry litter (high in N and P) could convert agricultural and urban wastes into a valuable organic fertilizer with environmentally beneficial nutrient release characteristics.

In an attempt to promote on-farm solutions to manage both rural and urban wastes, I conducted a field trial at the University of Maryland's Wye Research and Education Center on Maryland's Eastern Shore. The objectives of the study were to produce an organic amendment combining poultry litter and MSW compost that supplies adequate nutrients for crop production but minimizes the potential for off-farm contamination. In 1994, I evaluated co-composting of poultry litter and MSW and the N and P release characteristics of varying combinations when applied directly to the farm field. In 1995, I compared nutrient availability and grain crop uptake in fields to which either co-composted or fresh poultry litter had been applied following legume or cereal cover crops.

Results from the composting and nutrient release studies showed that we can modify both the magnitude and the pattern of soluble P and N released from an organic waste like poultry litter by combining it with a high-carbon material like MSW, and that these modifications can be tailored to meet crop demands. The 1995 field trial showed a negative effect on both soluble soil NO_3^-–N and corn biomass production from the combination of rye cover and poultry litter-MSW compost. Plots with crimson clover had slightly higher soil NO_3^-–N levels than rye plots over all fertility treatments. Preliminary analysis of results suggests that, if cover crops are to be used with MSW-poultry liter compost to supply crop nutrient needs, the cover crop should have a low enough C:N ratio to prevent N immobilization in the soil.

***Best Nutrient Management Practices on Watersheds to Protect Water Quality in Massachusetts.** *Jayaram Daliparthy, Stephen J. Herbert, Thomas J. Akin, and Betsey O'Toole. Department of Plant and Soil Sciences, Bowditch Hall, University of Massachusetts, Amherst, MA 01003.*

Environmental protection can be achieved through the adoption of improved nutrient management practices, especially in areas of critical environmental concern such as watersheds and coastal areas. Previous studies at the University of Massachusetts indicated that dairy manure application to perennial forages besides manure application to silage corn would greatly increase the land area for spreading, thereby decreasing the amount spread on any one field and thus reducing the potential for nitrate leaching. Such a practice could be vital on farms that have an excess of manure because of a high ratio of dairy cows to annually tilled land. Other studies showed that the application of fertilizers such as nitrogen, phosphorus, and potassium can be avoided by adopting proper nutrient management plans and crop rotations.

In a survey of Massachusetts dairy farmers, 96% tested their soils but only 20% calibrated their manure spreaders. A high proportion (65%) have no manure storage facilities. Planting cover crops can prevent soil erosion and runoff, thereby reducing the potential for eutrophication of lakes, ponds, and other water resources. Fall cover crops planted after silage corn harvest can also act as nitrogen scavengers, thereby preventing nitrate leaching. Conservation tillage practices coupled with the best nutrient management strategies will have a positive impact on water quality. Adoption of best nutrient management practices will also improve soil quality, agricultural sustainability, and farm economy. However, farmers' aversion to economic risk is identified as a major obstacle to the adoption of alternative technologies. A more pro-active role from the farming community is required for the adoption of many environmentally sound and economically sustainable strategies.

Energy from Agricultural Biomass

***Environmental Enhancement Using Short-Rotation Woody Crops and Perennial Grasses as Alternatives to Traditional Agricultural Crops.** *Virginia R. Tolbert[1] and Andrew Schiller.[2]*

[1]Biofuels Feedstock Development Program, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6422; [2]Oak Ridge Institute for Science and Education, Oak Ridge, TN 37831.

Short-rotation woody crops and perennial grasses are grown as biomass feedstocks for energy and fiber. When replacing traditional row crops on similar lands, these alternative crops can provide multiple environmental benefits besides enhancing rural economies and providing valuable feedstock resources. The U.S. Department of Energy is supporting research to address how these crops can provide environmental benefits to soil, water, and native wildlife species besides providing

bioenergy feedstocks. Research is underway to address the potential for biomass crops to provide soil conservation and water quality improvements in crop settings. Replacement of traditional erosive row crops with biomass crops on marginal lands and establishment of biomass plantations as filter strips adjacent to streams and wetlands are being studied. The habitat value of different biomass crops for selected wildlife species is also under study.

These studies have shown that in comparison with row crops, biomass plantings of both grass and tree crops increase biodiversity of birds; however, the habitat value of tree plantations is not equivalent to that of natural forests. The effects on native wildlife of establishing multiple plantations across a landscape are being studied. Combining findings on wildlife use of individual plantations with information on the cumulative effects of multiple plantations on wildlife populations can provide guidance for establishing and managing biomass crops to enhance biodiversity while providing biomass feedstocks. Data from site-specific environmental studies can provide input for evaluation of the probable effects of large-scale plantings at both landscape and regional levels of resolution.

***Perennial Grasses for Energy and Conservation: Evaluating Some Ecological, Agricultural, and Economic Issues.** *Mark Downing,[1] Marie Walsh,[2] and Sandy McLaughlin.[3]*

[1]Energy Division and Biofuels Feedstock Development Program; [2]Energy Division; [3]Environmental Sciences Division, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6422;

Perennial prairie grasses offer many advantages to the developing biofuels industry. High-yielding varieties of native prairie grasses such as switchgrass, which combine lower levels of nutrient demand, diverse geographical growing range, high net energy yields and high soil and water conservation potential, could and should supplement annual row crops such as corn in developing alternative fuels markets. Favorable net energy returns, increased soil erosion prevention, and a geographically diverse land base that can incorporate energy grasses into conventional farm practices will provide direct benefits to local and regional farm economies and lead to accelerated commercialization of conversion technologies. Displacement of row crops with perennial grasses will have major agricultural, economic, social and cross-market implications. Thus, perennial grass production for biofuels offers significant economic advantages to a national energy strategy that considers both agricultural and environmental issues.

***The Environmental Benefits of Cellulosic Energy Crops at a Landscape Scale.** *Robin L. Graham,[1] Wei Liu,[1] and Burton C. English.[2]*

[1]Biofuels Feedstock Development Program, Environmental Sciences Division, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831; [2]Institute of Agriculture, University of Tennessee, P.O. Box 1071, Knoxville, TN 37901-1071.

This paper presents a broad overview of the potential environmental benefits of bioenergy from energy crops — crops grown specifically to provide energy, such as corn produced for ethanol or wood produced for power plants. The environmental benefits of *using* biomass for energy must be considered in the context of alternative energy options, while the benefits of producing biomass from energy crops must be considered in the context of alternative land uses.

Using bioenergy will reduce both greenhouse gas emissions and air pollution if the bioenergy displaces fossil energy. Environmental benefits are greatest for coal displacement and least for natural gas. Bioenergy also avoids the safety and waste disposal problems of nuclear energy and the land loss and fishery concerns of hydropower. Because the production and use of bioenergy emits small net amounts of greenhouse gasses and creates some air pollution, it is less benign in these respects than other renewable energy forms (wind, solar, hydro).

Significant production of bioenergy will require dedicating large amounts of land to energy crops (200-400 ha per MW of base power; 150-300 ha per million liters of ethanol). Large-scale energy crop production will produce landscape and regional environmental benefits if perennial, low-input, cellulosic energy crops (e.g., short rotation tree crops or switchgrass) displace annual, high-input crops such as corn or soybeans. These benefits include better wildlife habitat, reduced erosion, increased soil carbon, and improved water quality. Quantifying these benefits requires a modeling approach; empirical data at a landscape or regional scale are not available because the crops are not yet widely grown. Development and applications of such an approach demonstrate the site-specificity of environmental benefits and the importance of including economic factors in predicting them.

Biomass Energy Crops: Production Costs and Supply. *Marie E. Walsh. Biofuels Feedstock Development Program, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831.*

Biomass energy crops are potential renewable sources of liquid fuels, power, and chemicals. The economic feasibility of these crops hinges on their prices being sufficiently low to be competitive with alternative energy feedstocks, yet high enough to provide a profit to farmers comparable to what they could earn in alternative uses for their land.

This paper presents estimates of the full economic cost (i.e., variable cash, fixed cash, and opportunity cost of owned resources including land) of producing switchgrass and hybrid poplars in six regions in the United States. Average production costs vary by region and yield, ranging from $30 to $59/dry ton for switchgrass bales, and $40 to $65/dry ton for poplar chips. Biomass prices are generally lower for switchgrass than for hybrid poplar, and are higher in the Lake States and Corn Belt than for other regions of the U.S.

Using a distribution of cropland rental rates as a proxy for the profitability of conventional agricultural crops, regional biomass supply curves are estimated. Assuming average U.S. yields of 5 dry ton/acre/year, approximately 300 million dry tons of switchgrass could be supplied nationally at farmgate prices of less than $30/dry ton. Approximately 250 million dry tons of woody crops potentially can be supplied nationally at farmgate prices of less than $40/dry ton. This is enough biomass to produce 20 to 33 billion gallons of ethanol at a feedstock price of $0.36 to $0.63/gal (depending on conversion efficiency), or 600 billion kWh at a price of $0.04 to $0.05/kWh.

Metropolitan Agriculture and Farmland Protection

Developing Nature-Based Tourism in Eastern Connecticut. *Norman Bender[1] and Nini Davis.[2]*

[1]Cooperative Extension System, University of Connecticut, Norwich, CT 06360; [2]Northeast Connecticut Visitors District, Putnam, CT 06260.

Farmers and other owners of agricultural lands, woodlands, and open space tracts in the northeastern United States face strong and persistent economic pressures to consider selling their properties for development purposes. Changes in the structure of agriculture and the spread of suburbanization into formerly rural towns can result in the evaluation of alternative uses of lands by the owners to provide viable incomes while maintaining their properties in current or related uses.

Rural land owners are exploring opportunities that may provide additional income and employment from nature-based tourism and recreation activities. Nature-based tourism, which involves agricultural and ecological enterprises, can contribute to meeting a combination of individual and societal needs. These include promoting economic development that creates employment opportunities through sustainable resources; maintaining a quality of life that includes preserving farmlands, open space and rural viewscapes; and maintaining economically and socially viable rural communities.

The paper describes a regional tourism development project designed to:

- Develop awareness of opportunities in the Eastern Connecticut region for nature-based tourism activities through a field survey, educational materials and workshops.
- Promote the region as a family-oriented tourist destination focusing on agricultural and natural resources by developing and distributing guides on farming, biking and hiking attractions.
- Coordinate selected outdoor recreational activities in the Northeast and Southeast Connecticut tourism districts, including a 50-mile bike tour and a hiking event.
- Achieve these objectives while developing a network of local farms, businesses, community officials, and agricultural and ecological organizations committed to further development of tourism while preserving the region's natural attributes.

The nature-based tourism development project initiated by the Northeast Connecticut Visitors District takes a collaborative approach involving Northeast and Southeast Connecticut visitors/tourism districts, agricultural and ecological businesses, and the University of Connecticut Cooperative Extension System. We provide an overview of the region's geography and economy, and describe the project's objectives, methods, and results (products and outcomes). We discuss the project's implications for developing a sustainable agricultural and ecological tourism industry in the northeastern United States that contributes toward maintaining the region's agricultural and natural resources.

***Empirical Evidence of Public Preferences for Farmland Preservation.** *Jeffrey Kline and Dennis Wichelns. Department of Environmental and Natural Resource Economics, University of Rhode Island, Kingston, RI 02881.*

Environmental amenities such as wildlife habitat, scenic vistas, and cultural values have become scarcer relative to food and fiber in developed countries. As a result, public concern has shifted from increasing agricultural production as a policy goal toward protecting and enhancing the quality of the rural environment. Conflicts arise between private and public interests when the decisions of landowners fail to provide socially optimal amounts of environmental amenities. Public policies can reduce these conflicts by encouraging landowners to manage farmland in a socially desired manner.

Choosing appropriate policies requires accurate information describing public preferences for the environmental amenities provided by farmland. We use qualitative information provided by focus groups and survey data from a sample of Rhode Island residents to identify and compare socially valued environmental amenities associated with farmland and other open space lands. The results provide empirical evidence that the public perceives significant environmental amenities associated with farmland, such as wildlife habitat and groundwater protection.

Rhode Island residents believe that protecting the environmental amenities associated with farmland is more important than protecting local agricultural production or maintaining farming as a way of life. In Rhode Island, public preferences for preserving farmland compare favorably with preferences for preserving other types of open space. The characteristics of these preferences regarding specific amenities are useful in designing public policies that protect and enhance the environmental benefits provided by farmland and open space.

***Protecting Important Natural Areas, Wildlife Habitat and Water Quality on Vermont Dairy Farms through the Vermont Farmland Protection Program.** *Alex Considine,[1] John Roe,[2] and Kate Willard.[3]*

[1]Vermont Land Trust, 8 Bailey Ave., Montpelier, VT 05602; [2]The Nature Conservancy, 27 State St., Montpelier, VT 05602; [3]Vermont Department of Agriculture, Food & Markets, 116 State St., Drawer 20, Montpelier, VT 06520.

Vermont has an active farmland conservation program designed to protect the state's best agricultural land and, to the extent possible, important natural areas, recreational sites and historical resources. The Vermont Department of Agriculture and the Department Fish and Wildlife, Vermont Land Trust and The Nature Conservancy have worked together in the state's most active farming areas to protect high quality farmland associated with critical wildlife habitat along wetlands and river banks in three separate conservation projects. The objectives in these projects were: to conserve good quality farmland to enhance the farm's viability; to protect critical wildlife habitat; to enhance water quality; to protect state threatened/endangered species; and to provide public access for hunting and fishing.

The result has been permanent conservation of four viable family dairy farms that also provide direct environmental benefits. A variety of methods have been used, including easement and fee purchase, easement donation, and regulatory requirements for building setbacks. In all the properties, vegetated buffer strips either were established or were permanently preserved for the purposes stated above. In some cases, cropped grassland buffers were created, designed to reduce runoff to open waters. In other cases, undisturbed buffers, either existing or created, were needed to insure protection of critical

habitats or waterfowl nesting areas. Providing public access for hunting on some of the buffers was particularly relevant because the agricultural land provides important staging areas for migrating waterfowl.

***Regional Farmers' Market Development as an Employment and Economic Development Strategy.** *John S. Nettleton. Cornell University Cooperative Extension, New York City Programs, 16 E. 34 St., 8th Fl., New York, NY 10016.*

Cornell University Cooperative Extension/New York City Programs has joined with Extension programs in surrounding counties and with not-for-profit groups based in New York City to form the "New Farmers/New Markets" Program. This is an effort to: 1) expand participation in existing and newly established farmers' markets (25 presently in NYC); 2) train neighborhood residents, primarily youth, to grow crops for market as part of a team-building and skills development effort based in camps and retreats surrounding the city, and; 3) train new immigrants and interested adults in farm market production, with primary emphasis on organic and sustainable production methods.

The efficacy of this strategy on a regional scale is examined as a demonstration that builds on the organizational advantages of each participant group. The Extension education network is statewide and longstanding; the not-for-profit summer facilities can benefit from added programs during the summer, reduced operating costs from fresh fruits and vegetables grown on site, and the potential for year-round program expansion with neighborhood residents in the city. For participating youth, the program provides an opportunity to gain an understanding of the food system, increase science and mathematics literacy skills in a hands-on and experiential process, and learn social and marketing skills through face-to-face marketing of the produce they have grown.

Long-term planning will engage civic grouping representing new immigrants, where recent traditions of agriculture offer the potential for participation and a variety of niche marketing options keyed to farmers' markets in multicultural settings. Fallow and productive farmland throughout the metropolitan area offers near-term potential for groups of cooperating producers, while the labor-intensive aspect of organic production avoids some start-up capital requirements of traditional production agriculture. The program aims to link local and regional groups involved in farm market production with land preservation groups and trusts active throughout the region.

Urban to rural linkages already established and underway are discussed, showing concrete examples of interagency and group collaboration.

***Community Food Security, Agriculture, and the Environment: A Massachusetts Perspective.** *Hugh M. Joseph. School of Nutrition Science and Policy, Tufts University, Medford, MA 02155.*

Community Food Security (CFS) is an emerging strategy to address hunger, access to food, and environmental concerns through a comprehensive food systems approach. It is an adaptation of the food security model, and integrates agriculture, food supply, nutrition and other local food system elements with broader socioeconomic objectives at the community level. An important goal of CFS is to link concerns such as environmental protection and preservation of local farming with urban-based priorities such as reducing hunger and expanding access to affordable food in the inner city.

Examples of established programs that fit the CFS model include farmers' markets, community gardens, and inner-city cooperative supermarkets. Some recent initiatives involve more integrative strategies. For example, the Western Massachusetts Food Bank developed a Community Supported Agriculture farm that provides fresh produce for hundreds of paying households while supplying thousands of pounds of free food each season to hungry people. Similarly, the Farmers' Market Nutrition Program promotes better nutrition for WIC recipients while supporting farmers' markets in low-income urban areas. These programs demonstrate the benefits of farming in states such as Massachusetts to urban residents, and they build farmers' support for problems that affect the city and the poor.

CFS holds the promise of bringing together usually disparate interests to address food system concerns in a more integrated manner. CFS will thereby demonstrate the environmental benefits of local agriculture to urban constituencies while broadening support for these issues among diverse interests including community development, anti-hunger, environmental, and public health/nutrition groups. It will similarly reduce the relative isolation of agricultural issues among groups involved with other environmental or food system concerns and programs.

With declining farming and rural populations and the resulting decline in their political representation, agriculture relies increasingly on urban-based policy makers and consumers for support. In Massachusetts, the urban vote has been critical for programs that preserve farmland, help farmers address environmental problems, and provide marketing and other economic opportunities that sustain local agriculture. Strategies that maintain consumer as well as local, state, and federal support for regional agriculture are critical elements for this sector's long-term sustainability. CFS advocates and associated anti-hunger, environmental, and community development groups can articulate the importance of community-based food and farm projects that expand awareness of, and support for, Massachusetts agriculture and related environmental benefits among the public and politicians.

Land Protection as Environmental Enhancement Through Agriculture. *Thomas E. Duston. Department of Economics, Keene State College, 229 Main Street, Keene, NH 03435-2001.*

Land protection, defined as the permanent removal of parcels or corridors of land from development consideration, is an important objective for a variety of conservation interests. These interests include large, well-established organizations like the Sierra Club, the Conservation Law Foundation, and the Audubon Society; international political movements such as the "Greens"; local organizations interested in pathways, greenways, and parks; and the growing number of economists, environmental biologists, and regional planners pursuing the elusive concept of "sustainable economic growth." Land protection clearly enhances the environment, whether by allowing the development of hiking trails, by creating wildlife corridors, or simply protecting aesthetically pleasing landscapes.

The question is: How can this type of environmental enhancement be related to agricultural practices?

The concept that connects land protection through agriculture to environmental improvements is that of *agricultural potential*. Land protection programs represent current environmental enhancement that comes not through current agriculture practices, but through the saving of the future agricultural potential of the land. Although admittedly it might not be the easiest thing politically to convert a town forest into a cornfield sometime in the future, it would be far more difficult to convert a piece of land that had become a shopping mall instead of a town forest. The shopping mall greatly restricts the future options on the land. In addition, we cannot anticipate what new methods of agriculture might be based in protected areas. Among these might be low impact "shade horticulture," hydroponic gardening in wetlands, or even the discovery of additional forest plants with medicinal uses.

In any case, the protection of the agricultural potential of the land as a current benefit of land protection seems to be ignored in cost-benefit calculations of the value of land protection. This paper takes the various methods of land protection—donation, easement, trust, land swap, purchase, bargain sale, and lease—and determines how the inclusion of agricultural potential affects the benefits and costs associated with the particular land protection method. Not surprisingly, the type of land protection method, as well as alternative tax structures and the nature of the land itself, are important variables in the analysis of land protection as environmental enhancement through the "banking" of agricultural potential.

A Conjoint Analysis of Farmland Protection Under a Purchase of Development Rights Program. *Maria C. Centenera and John Mackenzie. Department of Food and Resource Economics, College of Agricultural Sciences, University of Delaware, Newark, DE 19717.*

Farmland can be thought of as a heterogeneous good providing various benefits to residents of an area through combinations of its constituent attributes. Policy makers in the state of Delaware recently funded a statewide farmland purchase of development rights (PDR) program in an effort both to influence land use patterns and to enhance the state's agricultural industry. Residents benefit from not only the economic aspects of agriculture, but also the non-market environmental aspects.

While economic benefits are often reflected in market prices for farmland parcels, environmental benefits are more difficult to calculate. Consequently, PDR program officials lack objective and precise criteria to account for the broader environmental benefits of alternative farms. More generally, PDR programs themselves are not readily evaluated or justified by conventional benefit-cost criteria.

This study explores individual residents' preferences for protected farmland using conjoint analysis. This type of analysis allows for the calculation of willingness to pay for different farmland attributes, including non-market environmental attributes. Farmland attributes (and corresponding levels within each attribute) considered in this study are: farm parcel size (25, 40, 75, 120 and 2000 acres); cost per acre of development rights ($2,000, $4,000, $6,000, $8,000, and $10,000); farm type (crop, horse/livestock, and orchard/nursery); percent of parcel in forest (10% or 40%); proximity to already protected farmland (adjacent or not adjacent); percent of parcel's original road frontage that has been subdivided and developed (none, 25%, and 50%); owner's primary occupation (farming, not farming); pace of development (rapid or moderate); annual gross farm receipts ($12,000 or $60,000 per year); and expected long-term economic viability of farming in the area (poor or good). A survey of hypothetical combinations of these attributes was conducted using both graphic and word descriptions of the hypothetical bundles of farm attributes. Ratings and rankings for each hypothetical farm were then used to estimate an index reflecting residents' preferences.

There are many advantages of data collection through a survey of this nature. A conjoint survey can be administered to a wide range of audiences, and the results are easily interpreted. In this case, the results can be used by PDR program officials to make objective decisions regarding which candidate farms to protect. Alternatively, the results can be used to evaluate the program as a whole after farms have been protected. The question then becomes "Did the program maximize public benefits through its allocation of PDR funds?"

Agriculture Environmental Management and Community Relations. *Nathan Leonard,[1] Duncan Hilchey,[2] and Bernadine Italiano.[3]*

[1]PRO-DAIRY, Cornell Cooperative Extension, [2]Farming Alternatives Program, and [3]Cornell Cooperative Extension, Ithaca, NY 14853.

Agriculture environmental management is receiving high priority from both farm and nonfarm interests. Complaints frequently arise around larger farm operations even when they maintain excellent environmental management. Cornell Cooperative Extension is publishing material encouraging greater understanding, communication, and conflict resolution between farmers and neighbors to support sustainability of agriculture in communities.

Agriculture is often a preferred land use because it has considerably less environmental impact than most alternative uses. However, as nonfarm residents come in contact with agriculture, conflicts occasionally arise. Even commonly accepted farm practices may disturb communities. Frequently, environmental concerns are the triggering issues.

Farm and neighbor relations are often strained as farms increase in size. A landmark lawsuit in New York (C.A.R.E. vs. Southview Farm) offers an extreme example of what can happen if a community group takes issue with environmental management on a farm. Although manure odor was the triggering concern, the issues brought to court involved accidental manure spills, manure runoff from fields, and elevated nitrate levels in neighboring wells. The cost of this case would exceed the ability of most farms to pay.

A new trend is for farms to open communications with neighbors. Visiting neighbors, writing letters, hosting meetings, and inviting people to the farm are among the strategies being used to communicate. Farmers also are asking people to request manure spreading adjustments to avoid interfering with special events.

Farmers also have concerns. These range from property line disputes to vandalism. Communications and proactive conflict resolution skills are enabling farmers and

neighbors to solve their concerns. Greater understanding often dissolves issues. Sometimes farmers have no awareness of a problem and are willing to change practices even at great expense.

National and Provincial Policies on Agriculture and the Environment

***"The Living Countryside": Maintaining Sweden's Agrarian Landscape.** *David Vail. Department of Economics, Bowdoin College, Brunswick, ME 04011.*

Sweden, like its northern European neighbors, has a long history of measures to maintain an open and varied agrarian landscape. The intention has been to counteract three tendencies: loss of arable land to development; reversion of open land to forest; and landscape "rationalization," a part of agricultural industrialization. The latter tendency has been reinforced by policies encouraging increased farm scale, specialization and mechanization.

In the late 1980s, two farmland protection measures were introduced: a multiyear contract system that pays rents for maintenance of biologically rich, scenically beautiful, and culturally valued meadows and pastures; and conversion grants to restore wetlands, hedgerows, and other landscape elements previously lost through rationalization. Taking account of the land's "public goods" value, these initiatives were cost- effective.

The political economy behind these initiatives centered on the state's search for low cost ways to reduce food surpluses, but it also was influenced by farm interest groups' "rent protecting" behavior, the Department of Environmental Protection's critique of agriculture's environmental impacts, and environmental organizations' mobilization of public opinion behind farmland protection.

Other agricultural policies of the late 1980s, all intended to reduce farm output, also affected the rural landscape. Three measures — financial subsidies for conversion to organic farming, animal rights legislation mandating increased grazing, and a cover crop requirement in the voluntary acreage setaside — had positive landscape effects. However, subsidized afforestation of arable land, particularly in already heavily forested regions, contradicted the goal of an open and varied landscape.

Two major policy changes in the 1990s — a market-oriented food policy (1990) and European Union membership (1995)— have had complex and contradictory effects on both the extent and the qualities of Sweden's agrarian landscape.

***The Provision of Countryside Amenities: External Benefits of Agricultural Production in Mountainous Regions.** *Franz Hackl and Gerald J. Pruckner. Department of Economics, University of Linz, A-4040 Linz/ Auhof, Austria.*

This paper covers nonmarket services provided by farmers for recreational and residential purposes in several Central European regions. A regionally specified general equilibrium model is used to derive the efficiency conditions for a competitive equilibrium to guarantee a Pareto optimal outcome, and theoretical conclusions regarding compensation payments are drawn. We also present compensation models already used in Central Europe and assess them from an economic perspective.

The empirical analysis focuses on tourists' willingness to pay (WTP) for the provision of agricultural landscape services in Austria. The mean and median WTP of vacationers is 0.65 ECU and 0.25 ECU per person per day, respectively, with the figures varying according to the tourists' nationality. A comparison of these measures with current voluntary compensation payments made to farmers for preserving an agricultural countryside in several Austrian tourism communities suggests that results of hypothetical contingent valuation are of the right order of magnitude for the value of recreation-related agricultural services.

From an agricultural policy perspective, increased direct subsidies to farmers for the provision of countryside amenities and the application of environmentally sound production measures combined with a decrease of indirect price supports represent win-win options. Environmental improvements can be expected simultaneously with the stabilization of agricultural income levels, diminishing intrasectoral income differences, and the development of economically disadvantaged rural regions in Central European countries.

***Integration of Environmental Objectives into Agricultural Policy and Law in the Netherlands.** *Victor Bekkers and Jonathan Verschuuren. Faculty of Law, Tilburg University, P.O. Box 90153, 5000 LE Tilburg, The Netherlands.*

In the Netherlands, agriculture and the protection of the environment, especially of nature, have long been closely related. On the policy level, the same Department (Department of Agriculture, Fisheries and Nature) is responsible for both agriculture and protection of nature. This has influenced nature protection policy and legislation. A good example of how farmers are stimulated to preserve nature is the so-called "nature management contract": instead of imposing obligations and prohibitions by law, competent authorities can make contracts with individual farmers in which the farmers agree to run their farming business in a more ecologically balanced way. If they agree, the government compensates the farmers for possible reduction in profits that arise from this way of farming. The European Union strongly supports such measures.

More generally, we have observed a trend toward more external integration. This means that no longer is all environmental policy and law integrated into one Environmental Policy Plan or one Environmental Management Act. Instead, experience proves that integration of environmental objectives (quality goals) into each sectoral field of policy (e.g., agriculture) leads to better results. Internalization of environmental interests can be reached only when fully supported by the people in the relevant policy field (governmental authorities, farmers' unions and individual farmers).

We review the consequences of these new forms of steering: external integration of environment into agricultural policy and law; and, as an example, the nature management contract as an instrument to combine agricultural activities with protection of nature.

The Evolution of Environmental Enhancement Programs for Agriculture in Ontario. *Stewart Hilts. Centre for Land and Water Stewardship, University of Guelph, Guelph, Ontario N1G 2W1, Canada.*

Over the past five years, a coalition of farm groups in Ontario has developed a comprehensive Environmental Farm Planning Program. With extensive government support, it has been subject to a pilot evaluation and is now being implemented with a target of reaching 14,000 farm families in four years. In this paper the development of past environmental enhancement programs for agriculture and of the Environmental Farm Planning program are described. This program is one of the most comprehensive of such programs in the world, and is one of the few that have been organized and implemented by farm organizations themselves. Within it are numerous examples of environmentally positive agricultural practices in the context of a general strategy to enhance positive agriculture/environment interaction. The role of the rural landowner and the contribution of private stewardship to the enhancement of ecologically sustainable rural landscapes provide a theoretical context for the paper. Policy options are considered, with the conclusion that a voluntary, educational policy approach may provide greater measured benefits on the ground in the long run than regulatory or financial incentive policy options.

Agricultural Development and the Environment

***Resource Systems Analysis: Linking Agriculture and Environment in Central Java, Indonesia.** *Valerie Sexton. 63 St. Margaret's Bay Rd., Apt. 25, Halifax, Nova Scotia B3N 1J8, Canada.*

The island of Java is very fertile because of deposits from volcanic activity. In the lowlands, agriculture is quite stable, ecologically and economically. However, upland agriculture, as inherited from colonial times, is less economically beneficial and quite ecologically damaging because of accelerated soil erosion.

This need not be the case. One approach that permits a "win-win" situation for both upland agriculture and the environment has been attempted in Indonesia. The Faculty of Forestry at the University of Gadjah Mada, Yogyakarta, Indonesia, is in the midst of implementing a system of sustainable agriculture in the uplands of the Mangunan/Girirejo area of Central Java.

Resource Systems Analysis is a useful way to visualize how agriculture and related processes affect the environment and are in turn affected by it. The Resource Systems Framework indicates relationships among the physical environment and its functions, the main resource being processed, the final product, inputs required, by-products, distribution of the product, and consumption patterns as influenced by social organization, demographics, and political economy.

My research in Indonesia in 1992 specified the linkages that existed as the attempt was made to switch to more "environmentally friendly" types of agriculture. This occurred in response to the danger of loss of livelihoods from upland farming where agricultural methods were depleting the environment that ultimately had to sustain them.

Specifically, the extent of the intertemporal constraint faced by upland farmers in switching to tree and multicropping forms of agriculture was examined in terms of credit provisions: the capital needed; the capital available; and the best manner in which to raise and administer this capital according to existing social, political and economic institutions.

The case study indicates not only how to attain enhanced agricultural productivity and prevent pollution from pesticide runoff, but also how sound agricultural practices help to maintain watersheds, enhance water supplies, reintroduce native species, and maintain biodiversity; all of which in turn, sustain agriculture.

A Sustainable Alternative to Modern Rural Underdevelopment in a Period of International Integration. *David Barkin. Universidad Autónoma Metropolitana, Apartado 23-181, 16000 Xochimilco, DF, Mexico.*

The modernization of agriculture by the introduction of the Green Revolution technological packages impoverished small-scale farming communities and pushed institutions to discourage the use of intercropping patterns in favor of monocropping. Traditional multiproduct rural production systems have been threatened by the decline in the value of tradable products as international competition strongly influenced local market prices. Peasant producers are being forced to abandon their communities or are being pushed into more fragile ecosystems.

An alternative development model for sustainable regional development is being implemented in a depressed region of central Mexico. A diversified agricultural and agroforestry program is being combined with agro-industrial production along with community provision of on-farm services for recreation, eco-, nature- and cultural tourism, and environmental protection. This paper evaluates the conditions that led to the decline of the region and the social and productive processes being developed for its transformation.

***Are Productivity Enhancing, Resource Conserving Technologies a Viable "Win-Win" Approach in the Tropics? The Case of Conservation Tillage in Mexico.** *Olaf Erenstein. Natural Resources Group, CIMMYT Economics, Apdo. postal 6-641, 0660 Mexico DF, Mexico.*

Agricultural development experiences in the tropics suggest that addressing just productivity is generally unsustainable, whereas expensive resource-conserving practices are not necessarily economically viable. Productivity-enhancing, resource-conserving technologies opt for the middle ground, simultaneously addressing agricultural and environmental issues to achieve sustainable agricultural development. As such, these technologies have a "win-win" potential because they serve both agricultural and environmental interests.

Conservation tillage is an example of a productivity-enhancing, resource-conserving technology, as it potentially both reduces soil degradation and increases productivity. However, an array of agro-ecological and socioeconomic factors determine the impacts of the technology, both agricultural and environmental. Most of these factors are specific to the farming systems and environmental conditions of the tropics. This paper specifically reviews some advantages and disadvantages of conservation tillage in maize-based farming systems in the Mexican tropics. It concludes that productivity-enhancing, resource-conserving technologies such as conservation tillage are viable only in those locations where they actually would achieve their "win-win" potential.

Managing vertebrates in cover crops: A first study

K. Shawn Smallwood

Abstract. *Little is known of how vertebrate pest and beneficial species respond to cover crops in vineyards and orchards. During spring 1994 I interviewed 22 people who work with cover crops in California and searched for vertebrates and their signs in 36 field plots where cover crops were grown. Farmers usually relaxed concern for vertebrate pests after planting cover crops. But cover crops were thought to increase vertebrate damage to trees and vines when planted continuously across the rows or grown in orchards and vineyards less than three years old. Vertebrates usually were not abundant or harmful to the commercial crops and cover crops I examined. Gophers were most abundant in older, uneven, scrappy, or weedy cover crops. They preferred beneficial and insectary blends and Cahaba white vetch, and were least abundant in grasses, subclover mixes, and bur medic. Voles preferred nontillage clover mixes, but avoided bare ground under vine and tree rows. All small mammals were more numerous near streams and recently tilled fields. Cover crops attracted many predatory vertebrates, which improve the aesthetic quality of the farm and might keep animal damage to economically acceptable levels. Cover crops can contribute to wildlife conservation in California, especially if the area in cover crops continues to increase.*

Key words: California, conservation, gophers, voles, pest management, orchards, vineyards

Introduction

Cover crops are used in orchards and vineyards for various purposes, including erosion control, fertilization and nutrient management, reducing inputs of synthetic chemicals, improving water holding capacity of the soil, weed suppression, providing habitat for beneficial arthropods and fossorial invertebrates, and as trap crops for pathogens and animal pests (Miller et al., 1989). Most orchard and vineyard growers in California do not use cover crops, mainly because they are unconvinced of the benefits and fearful or suspicious of harmful consequences.

Vertebrate pests are a frequent concern among growers who are using or considering using cover crops. However, I found no published information on how cover crops affect vertebrate populations and whether these vertebrates pose increased risks to the commercial crops after cover crops are established. This lack of information seems even greater when one considers the many possible combinations of cover crop varieties and blends, commercial crops and varieties, site attributes, and management. Some combinations can increase populations of vertebrate species or the crop damage they might cause. Whereas vertebrates infrequently cause significant damage (Sullivan et al., 1987), rare cases of extensive damage with cover crops can discourage many growers from trying cover crops. Therefore, the risk of such damage must be minimized. An extensive research program will be needed to address how cover crops influence vertebrate populations and behavior, and how damage might be prevented or reduced. Bugg and Waddington (1994) provided the framework for such a research program for arthropods and cover crops in orchards and vineyards.

My study objectives were: to compare population levels of terrestrial vertebrate species that occur on vineyard and orchard cover crops; to identify the types and frequency of damage caused by vertebrates; and to suggest management strategies to minimize or prevent vertebrate-caused damage when cover crops are used. My focus was on potential vertebrate pests such as pocket gopher *(Thomomys bottae)*, California vole *(Microtus californicus)*, black-tailed deer *(Odocoileus hemionus)*, ground squirrel *(Spermophilus beecheyi)*, and black-tailed jackrabbit *(Lepus californicus)*. I also documented the occurrence of potentially beneficial vertebrates that prey on vertebrate and insect pests. This first study of how vertebrates interact with cover crops provides directions for more extensive research on preventing pest damage and improving wildlife conservation on orchards and vineyards.

Methods

During April and May 1994, I interviewed 22 people who work with cover crops in California, including farm managers, seed distributors, University of California Cooperative Extension Farm Advisors, researchers, and agricultural consultants (categories were compared only qualitatively). The interviews were not standardized, but the same general questions were asked regarding perceptions of vertebrate pest damage and current and past pest control on stands with and without cover crops. The experiences of the interviewees provided an early informational base on how vertebrates respond to cover crops.

I also searched for vertebrates and their signs on 36 vineyard and orchard plots with various mixes of cover crop varieties (Table 1). These fields were in the counties of Sonoma, Napa, Mendocino, Merced, and Yolo. I made wildlife observations along 18 km of transect during April and May 1994. Gopher signs included soil mounds and feeding hole plugs, both of which identify gopher burrows. Each gopher burrow usually contains one territorial individual, and sometimes a female with young (Bandoli, 1981). Vole signs included runways and open holes (often abandoned gopher

K. Shawn Smallwood is a Systems Ecologist, Consulting in the Public Interest, 109 Luz Place, Davis, CA 95616.

Table 1. Plant species used as cover crops by interviewees and on surveyed fields.

Individual Species

Annual Grasses: Annual ryegrass (*Lolium multiflorum*), Prairie brome (*Bromus catharticus*), Zorro fescue (*Festuca megalura*)

Perennial Grass: Blue wildrye (*Elymus glaucus*)

Annual Legumes: Berseem clover (*Trifolium alexandrinum*), Cahaba white vetch (*Vicia sativa, V. cordata*), Bell bean (*V. faba*), field pea (*Pisum sativum* ssp. *arvense*)

Mixes (Seeding rates only; actual composition of vegetation could differ)

Lohse Mill plow-down mix = 20% common vetch (*V. sativa*), 20% purple vetch (*V. benghalensis* L.), 15% lana woollypod vetch (*V. dasycarpa*), 40% peas (*Pisum sativum*), 5% oats (*Avena sativa*).

Germain's annual clover mix = 50% subterraneum clovers (*Trifolium subterraneum* L., includes Dalkeith, Koala, Karridale, Mt. Barker, and Nungaren subclovers), 30% barrel medic (*Medicago truncatula*), 10% crimson clover (*T. incarnatum*), 10% hycon rose clover (*T. hirtum*).

Nontillage mix, Napa & Sonoma Counties = 20% creeping red fescue (*Festuca rubra*), 20% blando brome (*Bromus mollis*), 10% hycon rose clover, 20% crimson clover, 30% subterraneum clovers.

Rich mix = 42% lana vetch, 15% common vetch, 10% meadow barley (*Hordeum brachyantherum*) & cereal rye (*Secale cereale*), 16% oats, and 17% crimson clover, bur medic (*Medicago polymorpha*) & mixed subclovers.

Lohse Mill beneficial blend = 15% cereal rye, 18% meadow barley, 18% Karridale subclover, 10% common vetch, 10% yellow sweetclover (*Melilotus officinalis*), 9% crimson clover, 5% alfalfa, 5% mustard, 5% wildflowers, 2.5% herbs, 2.5% vegetables.

Lohse Mill nontillage clovers = 60% subterraneum clovers, 20% bur medic, 10% hycon rose clover, 10% crimson clover.

Lohse Mill subclover mix = 33% Karridale, 33% Koala, 33% Clare.

Germain's insectary mix = 56% birdsfoot trefoil (*Lotus corniculatus*), 44% California buckwheat (*Erigonum fasciculatum*), crimson clover, hard fescue (*Festuca trachyphylla*), little burnet (*Sanguisorba minor*), baby blue eyes (*Nemophila menziesii*), sweet alyssum (*Lobularia maritima*), California poppy (*Eschscholzia californica*), yarrow (*Achillea millefolium*).

tunnels) with fecal material or food debris at the entrance. Both jackrabbits and ground squirrels usually were visible, but they also leave characteristic fecal material, and ground squirrels can be identified by their open burrows. Bird counts and surveys for mammal signs were usually conducted through the middle of a production unit and along the edge, where wildlife often aggregate. I counted gopher and vole signs within one vine or tree row of the transect, following the methods of Smallwood and Erickson (1995), and counted all wildlife within the line of sight. Gopher burrow counts along transect in Merced County were tested for mean differences due to cover crop varieties.

Results of Interviews

The most intense concerns regarding traditional vertebrate pest species were expressed by seed distributors and consultants (Table 2); farmers usually did not give vertebrates much attention beyond establishing deer fences before planting cover crops and occasionally baiting for ground squirrels and gophers. Only one interviewee used any vertebrate pest control since establishing cover crops. Cover crops might hide evidence of gophers and voles from farmers who would then be less likely to monitor small mammal populations. However, one interviewee suggested that farmers have increased their vigilance for vertebrates in cover crops because of the common fear of damage from vertebrates.

Discontinuing the monitoring of vertebrates can let populations exceed economically damaging levels. For example, gophers in a cover crop were reported to have "gotten away" from the farmer's attention when they destroyed a lemon orchard with *Macrophylla* rootstock (Bob Cantisano, Organic Ag Advisors, Colfax, CA, personal communication, 1994). But small mammal populations were usually thought not to harm commercial crops when cover crops were grown. This neutral coexistence might be explained by the cover crop serving as an alternative, preferred food source. Perennial (nontillage) clovers were usually thought to be preferred by pocket gophers.

Interviewees thought cover crops increased gopher, deer, and vole damage to trees and vines when planted within two years after the trees or vines, or when planted continuously across the field. In both cases, the cover crops were thought to attract deer and voles near young vines. Continuous cover protects voles and gophers from aerial predators, so they can more readily girdle vines or trees. One interviewee reported that the use of nontillage cover crops reduced the number of rattlesnakes *(Crotalus viridis)* where previously there had been many.

Results of Field Surveys

Densities of vertebrate pests were usually not excessive in fields with cover crops,

Table 2. Growers' opinions of possible risks posed by the most important vertebrate pests of vineyards and orchards where cover crops are used. X denotes greater risk than x, identified during interviews.

Types of Damage	Pocket Gopher	California Vole	Ground Squirrel	Blacktailed Jackrabbit	Blacktailed Deer
Above-ground plant consumption		X	X	X[1]	X[1]
Root consumption	X	x			
Girdling	X	X	X		
Uneven ground, water channeling	X	x	X		
Undermining trees	X		X		

[1] Mostly when vines or trees are young, i.e., less than 3 years after planting of commercial crop.

and only gophers warranted count summaries (Table 3). The maximum pocket gopher burrow density I observed was 75% of field saturation, based on their typical home range sizes. Even when gopher populations were found at 75% of saturation levels in vineyards or orchards, damage was slight to both the commercial crops and cover crops. After 18 km of survey, or roughly 2,045 orchard trees and 4,675 grapevines, I found only two vines killed and one almond tree damaged by a gopher. Most replants were needed because of disease or mechanical damage. However, gopher consumption of lateral roots might have reduced growth.

Uneven, scrappy or weedy cover crops had more gophers and voles. Gopher abundance varied with county, cover crop, planting

Table 3. Pocket gopher abundance on cover crops observed during field surveys.

Cover Crop or Blends, County	Cover Planting Date	Crop Rows[1]	Transect Length (m)	Gophers per 100 m of Transect
Wine grapes, Napa, Sonoma & Mendocino Counties				
Nontillage mix	1992	B	1900	0.052
Nontillage mix	1992	B	700	0.000
Nontillage mix	1991	B	1200	1.500
Nontillage mix	1991	D	250	1.600
Nontillage mix	1989	B	700	0.143
Zorro fescue, mixed clovers	10/93	B	2000	0.150
Blando brome, zorro fescue, mixed clover	1992	B	700	0.571
Blando brome, mixed clovers	10/92	B	1200	0.250
Blando brome, blue wildrye, weeds	1989	B	400	0.000
Zorro fescue	1989	D	250	3.600
Weeds, zorro fescue	1984	B	650	1.385
Subterraneum clovers, bur medic	?	B	200	2.500
Crimson & rose clovers	?	B	100	0.000
Oat & field pea	?	B	100	3.000
Pears, Mendocino County				
Bur medic, hycon rose clover	?	B	200	5.000
Berseem clover, bur medic	?	B	200	5.000
Walnuts, Yolo County				
Nontillage mix	10/93	B	400	0.250
Bell bean	10/93	B	400	0.000
Common, lana & purple vetch	10/93	B	400	0.000
Field pea	10/93	B	400	0.250
Dalkeith, Koala & Karridale subclovers	10/93	B	400	0.000
Lohse Mill plow-down mix	10/93	B	400	0.000
Almonds, Merced County				
Rich mix	1994	B	800	0.000
Rich mix	1992	O	600	4.000
Blando & prairie brome, annual ryegrass	1992	B	800	0.500
Almonds, Merced County, covers interspersed & replicated twice, LSD Critical T = 2.2, $\alpha = 0.05$[2]				
Lohse Mill beneficial blend	11/92	B	196	6.633a
Cahaba white vetch	11/92	B	196	6.122ab
Germain's insectary mix	11/92	B	196	5.102abc
Hycon rose clover	11/92	B	196	5.102abc
Germain's annual clover mix	11/92	B	196	4.082abcd
Lohse Mill nontillage clovers	11/92	B	196	4.082abcd
Resident vegetation	11/92	B	196	4.082abcd
Blando brome	11/92	B	196	3.571bcd
Bur medic	11/92	B	196	2.551cd
Lohse Mill subclover mix	11/92	B	196	2.551cd
Zorro fescue	11/92	B	196	2.041d

[1] Crop rows were managed as: B = bare ground, D = herbicide-treated weeds left on ground, O = certified organic producer with no weed control except mowing.

[2] Treatments that do not share the same letter were different with 95% confidence.

date, and commercial crop management (Table 3). Gophers were usually denser in cover crops planted at least two years earlier (Fig. 1, Table 3), and at field edges, especially near streams or recently tilled fields. In a Merced County almond orchard that had interspersed, replicated cover crop treatments, gophers were most abundant in beneficial and insectary mixes and Cahaba white vetch; they were moderately abundant in resident vegetation and in both perennial and annual clover mixes, and least abundant in grasses, subclover mixes, and burr medic (Table 3). Voles generally preferred nontillage clover mixes, and they avoided bare ground under the rows of vines or trees. Ground squirrels were very rare. Jackrabbits were numerous only on Sonoma County vineyards in younger cover crops.

I observed 31 other vertebrate species using cover crops during my field surveys (Table 4). Cover crops attracted substantially more hawks, falcons, insectivorous birds, and western fence lizards than did surrounding fields with no cover crops. Nearly all these species consume invertebrates or vertebrates, thereby benefitting the commercial crop. Most of the farmers interviewed also noticed that beneficial wildlife species responded to cover crops. Although these beneficial species will never remove all the animal pests in cover crops, they might keep damage to economically acceptable levels, thereby reducing pest management costs. The positive response of wildlife to cover crops also might contribute to wildlife conservation in California, especially if the area in cover crops continues to increase.

Discussion

Most vertebrate species benefitting from cover crops also benefitted the commercial crop. I witnessed few cases of vertebrate-caused damage, but I was told of a few cases of extensive damage, mostly from gophers and voles. Voles will not always be a serious threat because their populations tend to fluctuate, with peaks about every four years (Krebs and Myers, 1974; Garsd and Howard, 1982). Where gophers occur rarely, voles are sometimes abundant; these species are territorial and partition the available space. Gopher control might sometimes increase vole populations by providing voles with ready-made tunnels and uncontested space (Smallwood and Geng, 1993a). Vertebrate pest control often is used even though it is not warranted, resulting in unnecessary expense. Such control sometimes results in other types of damage. For example, artificial burrows made by the tractor-drawn "burrow-builder" bait applicator can cause plant loss and erosion from water channeling (Smallwood and Geng, 1993a). Also, persistent removal of gophers can reduce the soil qualities that promote plant growth (Abaturov, 1972; Laycock and Richardson, 1975; Mielke, 1977; Hole, 1981; Huntly and Inouye, 1988).

Vertebrate pest management usually fails to achieve its goals when it is reactive rather than preventive (Hill, 1990). The area in which vertebrate pests are managed is usually much smaller than the area in which they move and reproduce (Smallwood and Geng, 1994). Gophers and voles removed from a single field will soon be replaced by dispersers from nearby areas (Sullivan, 1986; Smallwood and Geng, 1993a). These dispersers move across the landscape in search of vacant home ranges. For a short time after they invade vacant areas, they are more likely to live at higher densities and to be food-stressed because they are rearranging burrows and home ranges (Sullivan, 1986). Immigrant gophers might be more likely to cause crop damage following gopher control. Reactive strategies are usually too late because the damage has been done and the population increase already has momentum that is difficult to disrupt.

Preventive strategies for vertebrate pest management usually do not involve efforts to reduce populations, but instead to reduce access or damage to the commercial crop (Van Vuren and Smallwood, 1996). Cover cropping serves as a preventive strategy by providing potential pests, such as gophers, with alternative food sources. Additional preventive strategies in cover crops can include barriers and predator enhancement. Cylindrical seedling protectors prevent gophers, voles, and jackrabbits from attacking young trees or vines during their most vulnerable growth stage (Adams and Weitkamp, 1992). Removing the vegetation under vine and tree rows exposes approaching voles to aerial predators (Birney et al., 1976; Fitzpatrick, 1996), and can reduce vole damage substantially by promoting avoidance behavior or predation (Byers and Young, 1974; Godfrey, 1986; Sullivan and Hogue, 1987). Hawk perches (Smallwood et al., 1996) and owl boxes (Ingels, 1992) are low-cost ways of permitting predatory raptors to access fields to hunt vertebrate pests. Hunting can also be facilitated by mowing or use of low-stature cover crops. Both strategies can actually attract hawks, even though the density of voles will probably decrease (Baker and Brooks, 1981). Preventive strategies usually are cheaper and need be applied less frequently than reactive strategies.

Preventive strategies also pose no secondary hazard to nontarget species, nor do they remove food resources from predatory species. As more vertebrate pests are made available for capture by predators, predator

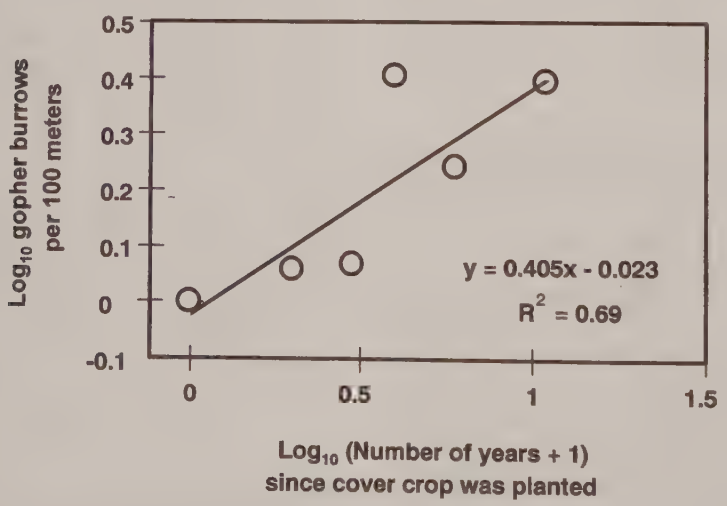


Figure 1. Increase in gopher densities with years of continuous growth of cover crops on vineyards. Densities were derived by dividing summed transect distances into number of gopher burrows counted.

Table 4. Other vertebrate species observed on or above cover crops during April and May, 1994.

Common Name	Scientific Name	Diet[1]	Associated cover crops
Western fence lizard	*Sceloporus occidentalis*	I	Nontillage mix
Pacific treefrog	*Hyla regilla*	I	Nontillage mix
Red fox	*Vulpes vulpes*	V,I,P	Nontillage mix
Coyote	*Canis latrans*	V	Nontillage mix
Raccoon	*Procyon lotor*	I,V,P	Nontillage mix
Red-tailed hawk	*Buteo jamaicensis*	V	Nontillage mix
American kestrel	*Falco sparverius*	I,V	Nontillage mix, rich mix
Merlin	*Falco columbarius*	V,I	Zorro fescue
Turkey vulture	*Cathartes aura*	C	Nontillage mix
Barn owl	*Tyto alba*	V	Rich mix
Western kingbird	*Tyrannus verticalis*	I	Rich mix
Scrub jay	*Aphelocoma coerulescens*	I,S	Rich, insectary, & plow-down mixes, grasses
American crow	*Corvus brachyrhynchos*	I,V,P	Blando brome & ryegrass
Yellow-billed magpie	*Pica nuttalli*	I,F	Lohse Mill plow-down mix
Western bluebird	*Sialia mexicana*	I	Nontillage mix
American robin	*Turdus migratorius*	I	Nontillage mix
Loggerhead shrike	*Lanius ludovicianus*	I	Grasses
Northern mockingbird	*Mimus polyglottos*	I	Grasses
European starling	*Sturnus vulgaris*	F	Nontillage mix
Mourning dove	*Zenaida macroura*	S	Nontillage & rich mixes, grasses
Tree swallow	*Tachycineta bicolor*	I	Oats & magnus pea
Killdeer	*Charadrius vociferus*	I	Nontillage mix
Valley quail	*Lophortyx californicus*	I,S	Nontillage mix
Mountain quail	*Oreortyx pictus*	I,S	Nontillage mix
House sparrow	*Passer domesticus*	I	Rich mix
White-crowned sparrow	*Zonotrichia leucophrys*	I,S	Bell bean, field pea, plow-down mix
Rufous-crowned sparrow	*Aimophila ruficeps*	I,S	Oats & magnus pea
Western meadowlark	*Sturnella neglecta*	I	Nontillage mix
Red-winged blackbird	*Agelaius phoeniceus*	I	Nontillage mix, grasses
Purple finch	*Carpodacus purpureus*	I	Nontillage mix
House finch	*Carpodacus mexicanus*	I	Grasses

[1] Diets were grouped as consumers of V = vertebrates, I = invertebrates, C = carrion (dead animal matter), P = plant matter, S = seeds and grain, F = fruits and nuts.

populations increase. Larger predator populations can apply greater hunting effort on more agricultural fields across the landscape, where they can regulate pest populations more. Larger predator populations will never control vertebrate pests completely, but they might reduce the risk of "outbreaks" and subsequent damage (Pearson, 1971). The conspicuous presence of vertebrate predators also enhances the aesthetic value of the farm and provides another basis for promoting cover cropping.

Fields with cover crops surrounded by conventionally managed fields are islands for wildlife on California's agricultural landscapes. They are attractive to wildlife for the same reason that alfalfa in the Sacramento Valley is preferred by wildlife (Smallwood and Geng, 1993b; Smallwood et al., 1996). Alfalfa and many cover crops are resource-rich and available to wildlife for many years. Pocket gophers proliferate in these environments, and they and their burrows are important resources for many animal species (Vaughan, 1961; Smallwood and Geng, 1993b; Smallwood et al., 1996), most of which are beneficial to the commercial crops. My preliminary research in cover crops shows that gopher populations can thrive in cover crops without causing significant damage to the commercial crops. Godfrey (1986) and Sullivan and Hogue (1987) show further that voles can coexist with commercial crops, so long as tree and vine rows are kept bare. Cover crops with bare rows appear to promote small mammals while also protecting the commercial crops. Cover crops that provide habitat for wildlife also serve to connect remnant habitat patches on agricultural landscapes.

More research is needed to determine whether cover crops can serve as a preventive management strategy by diverting vertebrate pests away from the commercial crop. Comparisons are needed of vertebrate-caused damage levels and pest abundance in various cover crop management systems and in orchards and vineyards with and without cover crops. Until further research results are available, I recommend that orchard and vineyard growers use cover crops but leave vine and tree rows bare. Also, they should not control small mammal populations unless absolutely necessary. I also recommend that growers place owl boxes and hawk perches in their fields.

Acknowledgment. I appreciate the contributions made by Zach Berkowitz, Daniel Bosch, Robert Bugg, Bob Cantisano, Dave Dyer, Dennis Hall, Lonnie Hendricks, Chuck Ingels, Anne Kraemer, Jeff Lyon, Craig McNamara, Rick Miller, Lee and Richie Moren, Mike Morris, Tom Nakashima, Scott Steinmous, Fred Thomas, Ernie Weir, Al White, and Greg Wittenborn. Travel expenses were paid by the University of California Sustainable Agriculture Resources and Education Program. I also thank Michael Morrison, Kerry Fitzpatrick, and an anonymous reviewer for their helpful comments on previous drafts of this manuscript.

References

1. Abaturov, B.D. 1972. The role of burrowing animals in the transport of mineral substances in the soil. Pedobiologia 12:261–266.
2. Adams, T.E., and W.H. Weitkamp. 1992. Gophers love oak — to death. California Agriculture 46:27–29.

3. Baker, J.A., and R.J. Brooks. 1981. Distribution patterns of raptors in relation to density of meadow voles. Condor 83:42–47.
4. Bandoli, J.H. 1981. Factors influencing seasonal burrowing activity in the pocket gopher, *Thomomys bottae*. Journal of Mammalogy 62:293–303.
5. Birney, E.C., W.E. Grant, and D.D. Baird. 1976. Importance of vegetative cover to cycles of Microtus populations. Ecology 57:1043–1051.
6. Bugg, R.L., and C. Waddington. 1994. Using cover crops to manage arthropod pests of orchards: a review. Agriculture, Ecosystems and Environment 50:11–28.
7. Byers, R.E., and R.S. Young. 1974. Cultural management of pine voles in apple orchards. HortScience 9:445–446.
8. Fitzpatrick, K.J. 1996. Birds of prey and their use of agricultural fields. In W. Lockeretz (ed). Environmental Enhancement through Agriculture. School of Nutrition Science and Policy, Tufts University, Medford, Massachusetts. pp. 103–112.
9. Garsd, A., and W.E. Howard. 1982. Microtine population fluctuations: an ecosystem approach based on time-series analysis. J. Animal Ecology 51:225–234.
10. Godfrey, M.E.R. 1986. Cultural practices affecting montane voles in Washington apple orchards. In C.G.J. Richards and T.Y. Ku (eds). Control of Mammal Pests. Taylor and Francis Ltd., London, England. pp. 127–131.
11. Hill, S.B. 1990. Pest control in sustainable agriculture. Proceedings, Entomological Soc. Ontario 121:5–12.
12. Hole, F.D. 1981. Effects of animals on soils. Geoderma 25:75–112.
13. Huntly, N., and R. Inouye. 1988. Pocket gophers in ecosystems: Patterns and mechanisms. Bioscience 38:786–793.
14. Ingels, C. 1992. Birds of prey assist farmers. Sustainable Agriculture 5:5–8. University of California.
15. Krebs, C.J., and J.H. Myers. 1974. Population cycles in small mammals. Advances in Ecological Research 9:267–399. Academic Press, New York.
16. Laycock, W.A., and B.Z. Richardson. 1975. Long-term effects of pocket gopher control on vegetation and soils of a subalpine grassland. J. Range Management 28:458–462.
17. Mielke, H.W. 1977. Mound building by pocket gophers (Geomyidae): Their impact on soils and vegetation in North America. J. Biogeography 4:171–180.
18. Miller, P.R., W.L. Graves, W.A. Williams, and B.A. Madson. 1989. Covercrops for California agriculture. Division of Agriculture and Natural Resources, University of California, Oakland.
19. Pearson, O.P. 1971. Additional measurements of the impact of carnivores on California voles (*Microtus californicus*). J. Mammalogy 52:41–49.
20. Smallwood, K.S., and W.A. Erickson. 1995. Estimating gopher populations and their abatement in forest plantations. Forest Science 41:284–296.
21. Smallwood, K.S., and S. Geng. 1993a. Management of pocket gophers in Sacramento Valley alfalfa. California Alfalfa Symposium 23:86–89.
22. Smallwood, K.S., and S. Geng. 1993b. Alfalfa as wildlife habitat. California Alfalfa Symposium 23:105–108.
23. Smallwood, K.S., and S. Geng. 1994. Landscape strategies for biological control and IPM. In W. Dehai (ed). Proceedings, International Conference on Integrated Resource Management for Sustainable Agriculture. Beijing Agricultural University, Beijing, China. pp. 454–464.
24. Smallwood, K.S., B.J. Nakamoto, and S. Geng. 1996. Association analysis of raptors on an agricultural landscape. In D.M. Bird, D. Varland, and J.J. Negro (eds). Raptors Adapting to Human-Altered Environments. Academic Press, New York, N.Y. pp. 177–190.
25. Sullivan, T.P. 1986. Understanding the resiliency of small mammals to population reduction: poison or population dynamics? In C.G.J. Richards and T.Y. Ku (eds). Control of Mammal Pests. Taylor and Francis Ltd., London, England. pp. 69–82.
26. Sullivan, T.P., and E.J. Hogue. 1987. Influence of orchard floor management on vole and pocket gopher populations and damage in apple orchards. J. Amer. Soc. Horticultural Sci. 112:972–977.
27. Sullivan, T.P., J.A. Krebs, and H.A. Kluge. 1987. Survey of mammal damage to tree fruit orchards in the Okanagan Valley of British Columbia. Northwest Science 61:23–31.
28. Van Vuren, D., and K.S. Smallwood. 1996. Ecological management of vertebrate pests in agricultural systems. Biological Agriculture and Horticulture 12:39–62.
29. Vaughan, T.A. 1961. Vertebrates inhabiting pocket gopher burrows in Colorado. J. Mammalogy 42:171–174.

Conference Looks at Environmental Impact of Changes in Coffee Farming

The environmental impact of coffee production, particularly the conversion of much of the world's coffee lands from traditional shade plantations to "technified" coffee farms, was examined at a three-day "Sustainable Coffee Congress," sponsored recently by the Smithsonian Migratory Bird Center in Washington, D.C. The Congress was "the result of international concern over major changes in the way that coffee is grown," the Center said, including concern about environmental, social, and economic issues affecting coffee farms and farmers.

In the 1970s, coffee farmers began to abandon traditional growing methods in favor of new methods that relied on high-yield, densely packed dwarf coffee plants that grow in full sun. "These plants must be nurtured with fertilizer and protected against attack with an array of insecticides, herbicides, and fungicides," according to the Center.

"Lured by the prospect of higher yields, many farmers willingly chopped down the overstory, ripped out the old coffee plants, and replaced them with new ones, exposing bare soils to wind, sun, and rain. The main results have been increased erosion, polluted runoff, a substantial reduction in wildlife habitat, and increased exposure of workers to hazardous chemicals."

Research has revealed the importance of traditional coffee plantations worldwide, especially with natural forests dwindling, according to the Center.

"In the midst of altered and shrinking habitat, migratory birds have found a sanctuary in the forest-like environment of traditional coffee plantations," says the Center, which adds that many migratory birds prefer coffee plantations over natural forest.

"Of all agricultural systems in the tropics, shade coffee plantations have been found to have some of the highest numbers of individuals and species of migratory birds."

The linkage between pesticide use and pesticide residues

Fred Kuchler, Ram Chandran, and Katherine Ralston

Abstract. *Newly available data from USDA's Pesticide Data Program allow us to trace pesticide residues on fruits and vegetables to their sources among various uses. We show that pesticide residues come from four sources: on-farm pesticide use; post-harvest pesticide use; pesticide use on imported food; and canceled pesticides that persist in the environment. Post-harvest pesticides account for the largest share of residue detections. Farmers' pest control choices influence consumers' dietary intake of pesticides, but the way in which food is marketed and the history of pest management techniques used on farms may have a greater influence. For pesticides that U.S. farmers currently use, the data show the geographic sources of residues and the extent to which use contributes to dietary intake risks. This information could be used to target development of pest control alternatives more narrowly. However, research to develop on-farm pest control alternatives will not address all pesticide residue risks in consumers' diets.*

Key words: pesticide dietary intake, postharvest pesticides

Introduction

Understanding the linkage between pesticide use and pesticide residues in the food supply will help regulatory agencies reduce risks from dietary intake of pesticides while minimizing disruptions to food production. At the least, when basic elements of the linkage are documented, regulators can focus on uses that contribute significantly to consumers' risk of pesticide dietary intake. Also, establishing the linkage could help set priorities so that publicly supported scientists attempting to develop alternatives to pesticides can begin with the riskiest pesticide uses.

Our analysis of a new, large-scale survey of pesticide residues on fresh fruits and vegetables reveals that consumers' dietary intake of pesticides comes from four sources: domestic, on-farm pesticide use; post-harvest use; pesticides on imported foods; and pesticides whose registrations have been canceled but that persist in the environment. The newly available data from USDA's Pesticide Data Program cover 10 commonly consumed fruits and vegetables and 50 pesticides. Our results, based on this broad but not exhaustive coverage of pesticides on foods, strongly suggest that agricultural research or other risk reduction initiatives must look beyond on-farm pesticide use to reduce dietary intake of pesticides.

In recent years, proposals intended to reduce consumers' dietary intake have focused on reducing risks only from domestic, on-farm use. For example, the pesticide proposal of the Clinton Administration, issued in September, 1993, called for 75% of farmland to be under integrated pest management by the year 2000 (Kuchler et al., 1994). Furthermore, some more recent Federal programs designed to support development of non-pesticide pest control methods clearly equate reduced on-farm pesticide use with reduced risk (U.S. Environmental Protection Agency, 1995a,b).

The Pesticide Data Program

The information in this report is based on data collected under USDA's Pesticide Data Program (PDP). Recognizing the need to improve the quality and quantity of information available on chemical residues, the administration initiated the PDP in 1991 to complement the President's Food Safety Program. The PDP is designed to improve the pesticide database by establishing pesticide residue monitoring activities and by expanding pesticide use surveys. The PDP provides data for government agencies to use in responding more effectively to food safety issues.

Pesticide use has been surveyed by USDA's National Agricultural Statistics Service (NASS) and the Economic Research Service (ERS), targeting use in fruit and vegetable production. Alternate annual surveys cover most vegetables in one year (starting in 1990) and fruits the following year (starting in 1991). Residue testing by USDA's Agricultural Marketing Service (AMS) provides residue data for individual commodities that may be significant contributors to total residue intake, especially for children.

The USDA Pesticide Residue Data

The AMS PDP fills an important gap in the data available on pesticide residues in the diet. The Food and Drug Administration (FDA) Total Diet Study measures total dietary intake of pesticide residues, but is not designed to show which commodity is the source of each pesticide residue. FDA's study is organized around foods as eaten, including processed foods that may be manufactured from many agricultural commodities. For many pesticides it would be impossible to use this type of study to determine which commodities are responsible for residues in processed foods and the source of those residues, since a processed item may contain several ingredients that could contribute residues of a given pesticide. Even if particular ingredients were shown to carry particular residues, residues could not be attributed to domestic pesticide use or

Fred Kuchler, Ram Chandran, and Katherine Ralston are economists in the U.S. Department of Agriculture, Economic Research Service, 1301 New York Ave., NW, Washington DC 20005-4788. Trade names are provided for the benefit of the reader and do not imply endorsement or preferential treatment by the authors or the USDA. The opinions expressed here are those of the authors and not necessarily those of USDA.

use on imported foods without a demanding new record-keeping task to trace commodity movements from the farm through marketing and processing channels. FDA also measures residues on commodities directly through its regulatory monitoring, but this program is focused on detecting residues that exceed tolerances rather than estimating the typical residue content of foods.

Alternatively, examining individual commodities helps reveal the source of each residue because shipping documents state whether produce is of domestic origin or imported, and where domestic produce was grown or packed. PDP pesticide use data specifies the location of use, and therefore, can be linked to residue data. Furthermore, comparing aggregate use and residue statistics reveals sources other than current on-farm use.

During 1992, the AMS PDP measured residues on samples of fresh fruits and vegetables, including apples, bananas, broccoli, celery, carrots, green beans, grapefruit, grapes, lettuce, oranges, peaches, and potatoes. (Broccoli and carrots were tested only during the final months of 1992 and were not included in this analysis.) The ten commodities tested over the entire year represent approximately 56% of total U.S. fruit and vegetable consumption. Samples included both imported and domestic commodities. Commodities were included in PDP based on their level of consumption. AMS PDP screened for 14 fungicides, 6 herbicides, and 30 insecticides (Table 1).

Table 1. Pesticides and commodities screened by AMS-USDA, 1992.

Herbicides and Growth Regulators	Insecticides and Miticides	Fungicides	Commodities
2,4-D	Acephate	Anilazine	Apples
Atrazine	Azinphos-methyl	Benomyl	Bananas
Bromoxynil	Carbaryl	Captan	Celery
Chlorpropham	Chlorpyrifos	Chlorothalonil	Green beans
DCPA	Cypermethrin	Dicloran	Grapefruit
Trifluralin	DDT	Diphenylamine	Grapes
	Demeton	HCB	Lettuce
	Diazinon	Imazalil	Oranges
	Dichlorvos	Iprodione	Peaches
	Dicofol	Myclobutanil	Potatoes
	Dimethoate	o-Phenylphenol	
	Disulfoton	PCNB	
	Endosulfan	Thiabendazole	
	Ethion	Vinclozolin	
	Ethoprop		
	Fenamiphos		
	Lindane		
	Malathion		
	Methamidophos		
	Methidathion		
	Methoxychlor		
	Mevinphos		
	Omethoate		
	Ethyl parathion		
	Methyl parathion		
	Permethrin		
	Phorate		
	Phosalone		
	Phosmet		
	Propargite		

The set of pesticides that fruit and vegetable farmers use partly overlaps the set of 50 pesticides for which AMS tested, but neither set entirely contains the other. Thus, AMS's testing program cannot be expected to render an exhaustive picture of residues in foods. The 1992 vegetable pesticide use survey alone documents use of 164 pesticides. However, the 50 in AMS PDP include many pesticides that fruit and vegetable farmers frequently use, as well as some not used in domestic, on-farm production practices. More than half the PDP pesticides were selected by EPA; the EPA list consists of pesticides whose toxicity it is evaluating, i.e., pesticides with acute and chronic endpoints, including suspected carcinogens (U.S. Dept. of Agriculture, 1994).

The AMS PDP pesticides cover different fractions of current, domestic, on-farm pesticide use for each commodity. The AMS PDP pesticides represent 75.5% of pesticides used on celery, by weight (calculated from U.S. Dept. of Agriculture, 1993). At the other extreme, AMS PDP pesticides cover 11.4% of preharvest pesticide use on grapefruit (calculated from U.S. Dept. of Agriculture, 1992). With sulfur excluded from the grapefruit calculation, AMS PDP pesticides cover 71.6% of use.

The samples were drawn from terminal markets and wholesale distribution centers in six states: California, Florida, Michigan, New York, Texas, and Washington. These states were selected because they cover a large portion (about 40%) of the U.S. population, thereby ensuring that the data give a good estimate of the prevalence of the 50 pesticides in a portion of the food supply. Testing laboratories treated samples as consumers would: they washed, peeled, and cored the samples as appropriate before measuring residues.

Residue Findings and the Linkage with Pesticide Use

Three outcomes are possible when testing for residues: A residue may be too small to detect (true value may be zero or any level below the detection limit); detected, but present in an amount too small to measure accurately (at least as large as the detection limit, but smaller than the quantitation limit); or detected and measured. If a residue is measured, it may exceed or fall below the legal food tolerance. AMS PDP shows higher detection rates than the commodity-specific data from the FDA regulatory monitoring program: only 39% of samples contained no detectable residues. In contrast, in 1992, FDA found no detectable residues on 51% of fruit and 69% of domestic vegetable samples. Similarly, no residues were found on 57% of fruit and 66% of

imported vegetable samples (U.S. Dept. of Health and Human Services, 1993).

AMS and FDA report results of similar tests, but the agencies have different information needs and therefore test in different ways. AMS focuses on detecting residues, no matter how small, while FDA's interest is in enforcement and in measuring residues that might violate legal tolerances. FDA's testing is necessarily limited because the methods used for regulatory monitoring are designed to obtain test results quickly. These differences account in part for differences in detection rates found by the two programs.

FDA and AMS findings share some characteristics. The fraction of AMS sample residues that exceed legal tolerances is similar to the level measured by FDA (approximately 1%). This indicates that the real difference between the programs lies in the resources each devotes to measuring very small residues.

The Importance of Weather and Exposure to the Elements

Some characteristics of the linkage between pesticide use and pesticide residues are obvious from examining descriptive statistics calculated from pesticide use surveys (U.S. Dept. of Agriculture, 1992, 1993) and the residue survey (U.S. Dept. of Agriculture, 1994). One is that most on-farm pesticide applications do not lead to detectable residues on food.

AMS detected the pesticides most frequently used on farms, but at rates far smaller than their use would suggest. Chlorothalonil is one of the most frequently used fungicides on green beans. In 1992, 36% of green beans were treated with chlorothalonil an average of 3.4 times. Chlorothalonil was found (at any level) on 7.1% of green bean samples. Captan is the most heavily used fungicide on apples, with 52% of apples receiving an average of 7.3 treatments. Captan was found on 7.3% of apple samples. (Even this proportion may overstate the importance of farm use of captan as a source of residues since captan also may be used post-harvest.) These relations reinforce the well-known findings that time and exposure to the elements greatly reduce many pesticide residues (Eichers et al., 1971; Elkins, 1989; Gonzalez et al., 1989).

Post-harvest residues, in contrast, are much less likely to have broken down by the time a commodity comes to market. Post-harvest pesticides, by definition, are applied later than pesticides applied on-farm, and are not much exposed to rain, wind, high temperature, sunlight, or alkali soils. Furthermore, the post-harvest pesticides are applied directly to edible products, often in a wax to ensure that they remain in contact with the surfaces of fruits and vegetables.

The PDP data show that post-harvest residues are indeed detected more frequently than on-farm uses. Table 2 shows the 20 most frequently detected pesticides by commodity. Just five combinations of pesticide and commodity yielded more than half the samples with positive findings, all from post-harvest pesticide uses. When we rank pesticide detection frequencies by commodity, the top six pesticide-commodity combinations all come from post-harvest treatments. (We inferred that these detections result from post-harvest treatments because these pesticides are registered for post-harvest use and there is no evidence of on-farm use, except for iprodione and dicloran on peaches. Detection frequencies greatly exceed the fraction of peaches treated with iprodione and dicloran.)

For some commodities, almost all pesticide residue detections came from post-harvest treatments, e.g., 98, 90, and 88% for bananas, grapefruit, and oranges, respectively. Individual growers and shippers have incentives to use post-harvest fungicides to reduce losses in shipping and to enhance shelf-life, but the public sector sometimes adds to those incentives. For example, the Florida Department of Citrus requires post-harvest use of fungicides and sets minimum residue standards (State of Florida, 1994). The fungicides detected on bananas are fungicides used post-harvest on other domestically grown commodities. Thus, we inferred that the fungicide detections on bananas resulted from post-harvest treatments.

Table 3 shows, for each of the ten commodities, the number of residue detections from all sources, the number of detections possibly from post-harvest use, and the relative shares among detections of post-harvest pesticides. Here, we counted detections as possibly from post-harvest treatments if pesticides are registered for post-harvest use. The table also shows the individual pesticides detected post-harvest. Note that the shares cannot be precisely measured because some pesticides, like captan on apples, are used on the farm and are registered for use in the packing house. Post-harvest

Table 2. Ranked detection frequency by pesticide and commodity.

Commodity	Pesticide	Detection Frequency (%)
Oranges	Thiabendazole	63.8
Potatoes	Chlorpropham	59.3
Apples	Thiabendazole	56.5
Peaches	Iprodione	54.4
Grapefruit	Thiabendazole	54.0
Peaches	Dicloran	46.7
Celery	Permethrin	38.6
Bananas	Thiabendazole	37.5
Celery	Chlorothalonil	32.3
Apples	Azinphos-methyl	31.4
Apples	Diphenylamine	30.5
Oranges	Imazalil	29.3
Grapes	Iprodione	29.2
Grapes	Captan	27.9
Green beans	Methamidophos	27.7
Celery	Dicloran	27.6
Green beans	Endosulfan	27.0
Celery	Acephate	26.8
Green beans	Acephate	25.3
Grapes	Vinclozolin	23.6

Table 3. Significance of post-harvest residues among AMS-USDA pesticide residue detections.

Commodity Pesticide	Total Number of Residue Detections	Number of Detections Possibly from Post-harvest Use	Post-Harvest Residues as % of All Detections
Apples	1096	518	47.3
Captan		45	
Diphenylamine		173	
o-Phenylphenol		7	
Thiabendazole		293	
Bananas	221	217	98.2
Imazalil		23	
Thiabendazole		194	
Celery	854	0	0.0
Grapefruit	332	298	89.8
Imazalil		87	
o-Phenylphenol		1	
Thiabendazole		210	
Grapes	756	35	4.6
Dicloran		35	
Green beans	576	0	0.0
Lettuce	297	0	0.0
Oranges	482	422	87.6
Imazalil		167	
o-Phenylphenol		5	
Thiabendazole		250	
Peaches	677	364	53.8
Dicloran		168	
Iprodione		196	
Potatoes	530	387	73.0
Chlorpropham		337	
Thiabendazole		50	
All	5281	2241	38.5

pesticides take the largest share of detections for potatoes and most fruits, but not for other vegetables.

Residues on Imported Foods

Residues on imported fruit and vegetables can be a significant source of consumers' pesticide dietary intake only to the extent that imported foods compose significant shares of fruit and vegetable consumption. Overall, imported fruits and vegetables are approximately 19% of U.S. fresh fruit and vegetable consumption by weight (Love, 1995). That share has grown from 16% in 1987. The percentage varies by commodity. Potatoes are the most-consumed vegetable in the United States, at 49 lb per capita annually, with 5% imported. U.S. consumers eat more bananas than any other fresh fruit (27 lb annually and trending upward). Almost all bananas are imported (U.S. Dept. of Agriculture, 1995). Imports currently account for over 50% of net domestic consumption of noncitrus fruit and 8% of citrus. Vegetables and melons come largely from domestic production, with 15% imported.

AMS PDP data confirms that imported fruits and vegetables are a source of pesticide dietary intake. Post-harvest fungicides were detected on bananas. Other commodities, like grapes and peaches, are both seasonally imported into the United States and produced domestically. Between 1990 and 1994, imports accounted for 37 to 38% of domestic consumption of grapes and 6–8% of peaches. Among the 10 AMS PDP commodities, only peaches and grapes had significant numbers of samples from both domestic production and imports. This characteristic makes these commodities useful for contrasting the residues on domestic produce and imports.

Calculating and comparing average residues for domestic and imported fruit is not straightforward because any average residue point-estimate has to be made under some assumption about the values of the unmeasured residues (residues that are below limits of detection and quantitation). However, it is possible to examine average residues calculated under extreme assumptions, i.e., calculating upper and lower limits for the estimates of average residues. These calculations allow us to draw a few conclusions with great confidence. For example, if the upper limit of the residue value for a given pesticide on domestic grapes is smaller than the lower limit for imported grapes, we can be sure that imported grapes typically carry more of that pesticide.

Two sets of assumptions allow us to calculate limits for average residues. To calculate the lower limit, we assume that all residues below the detection limit are zero and that all detections below the limit of quantitation are at the limit of detection. For the upper limit, we assume that all residues below the detection limit are at the limit of detection and that all detections below the limit of quantitation are at the limit of quantitation. We calculated these upper and lower limits for both domestic and imported grapes. Figs. 1 and 2 show the paired domestic and imported residue ranges for grapes. Each figure shows the five pairs of residue ranges for which differences between imported and domestic are largest, that is, the pairs with the least overlap.

Residues of only seven fungicides were detected on grapes; of those, diphenylamine and thiabendazole showed only one detection each on domestic grapes. The remaining five paired residue ranges are shown in Fig. 1. On grapes, there are three fungicides (captan, iprodione, and vinclozolin) for which the smallest possible imported average residue value is larger than the largest possible domestic average residue value.

Also, the differences are large compared with the range of physically possible average values. Captan residues are 9 to 22 times higher on imported than domestic grapes, iprodione residues 2 to 4 times higher, and vinclozolin residues 13 to 30 times higher. Dicloran and myclobutanil residues are

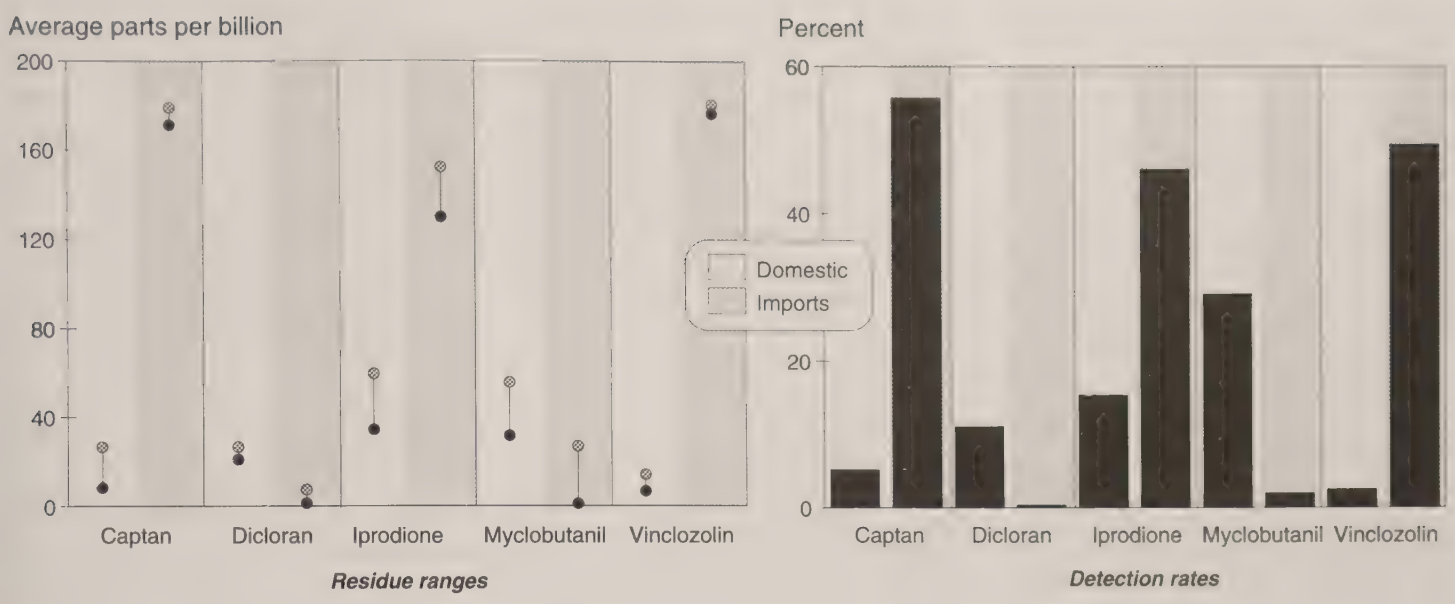


Figure 1. Average fungicide residue ranges and detection rates for grapes.

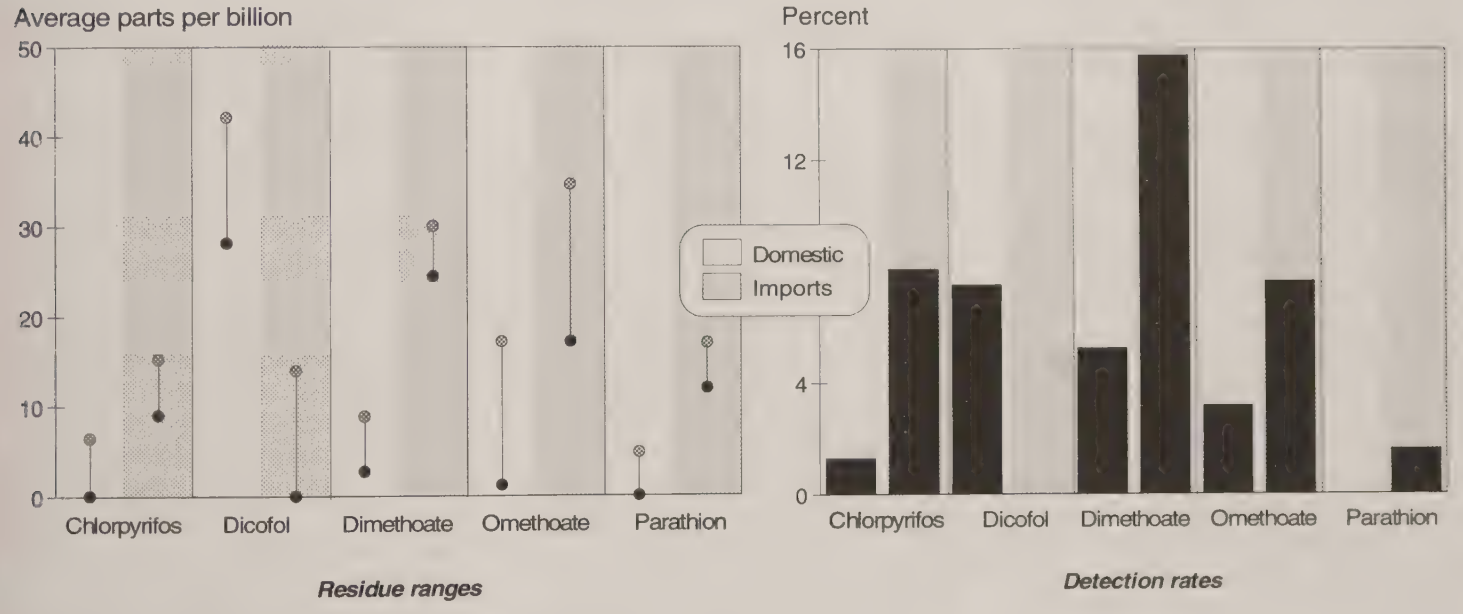


Figure 2. Average insecticide residue ranges and detection rates for grapes.

higher on domestic grapes, but detection rates and average residue ranges are lower for both domestic and imported grapes than for the other three fungicides.

Five paired ranges of average residues for insecticides on grapes are shown in Fig. 2. Twelve different insecticides were detected on grapes; however, four of these were detected just on one domestic or just on one imported sample. Among the remaining pesticides, five showed obvious differences between average residues. However, the detection rates for insecticides were far lower than for fungicides. Residues of chlorpyrifos, dimethoate, omethoate, and parathion clearly are higher on imported grapes. (Omethoate is not registered for use in the U.S. but does have an established tolerance.) Only dicofol shows unambiguously higher residues on domestic grapes.

The average residue ranges show that chlorpyrifos is at least 40% higher on imported grapes. Dimethoate residues on imported grapes are approximately 3 to 11 times higher than residues on domestic grapes. For omethoate, the high end of the domestic average residue range is equal to the low end of the imported average residue range. Dicofol residues on domestic grapes are at least twice those of imported grapes.

The Problem of Persistence

Farmers no longer use some of the chemicals for which AMS screened, including anilazine, DDT, demeton, and HCB.

AMS also screened for DDE and TDE, which are degradation products of DDT, their only possible source. TDE residues were not detected in the ten commodities. Although legal use of DDT ended in 1972, both DDT and DDE were found in samples of celery, lettuce, and potatoes. Residues of DDE alone were found in apples and green beans. DDT residues were found in peaches. These detections could have been the result of use up to 50 years ago.

The largest number of DDT and DDE detections among the 10 commodities was in potatoes. AMS screened 568 potato samples and found 530 cases of pesticide residues, distributed across 16 different chemicals. The largest share of residues was chlorpropham (337), followed by DDE (56) and thiabendazole (50). There were eight DDT residue detections. Thus, chemicals that persist in the environment accounted for 12% of residue detections in potatoes; current farm use of pesticides accounted for 15%, and currently used post-harvest chemicals for 73%.

The Sources of Risk from Domestic, On-farm Pesticide Use

We selected nine pesticides from the 50 for which AMS screened to further examine residues resulting from domestic on-farm use. These nine pesticides were found at levels that exceed 10% of the negligible risk level for at least one consumer subpopulation, and are currently used on-farm. (See Kuchler et al., 1996, for further details of risk calculations.) Subpopulations include five household income classes, four ethnic groups, and five children's age cohorts (annual age cohorts from ages 1 through 6). The nine pesticides are: acephate, azinphos-methyl, benomyl, captan, chlorothalonil, dimethoate, ethion, methamidophos, and permethrin.

We calculated point estimates of risk for each consumer subpopulation from each pesticide, where risk is a function of dietary intake and potency. Dietary intake is the product of average consumption of each commodity per kg of body weight and average residue of each pesticide. We estimated food consumption using the 1987–88 Nationwide Food Consumption Survey by USDA's Human Nutrition Information Service. Foods as eaten were converted to equivalent quantities of total consumption of raw agricultural commodities using TAS-DIET™ software by Technical Assessment Systems, Incorporated. Average residue was calculated following EPA guidelines, filling in unmeasured values by assuming that residues too small to measure accurately can be described by a uniform distribution (U.S. Environmental Protection Agency, 1992). For each pesticide, dietary intake was summed across the ten commodities to calculate total dietary intake for each consumer subpopulation.

For possible or probable human non-threshold carcinogens (benomyl, captan, chlorothalonil, and permethrin), we estimated cancer risk (an expected number of cancers per million consumers) as the product of dietary intake and EPA cancer potency estimates (Engler, 1993). Our definition of negligible risk followed the regulatory convention of one-in-a-million over a 70-year lifetime of dietary intake. For children's cohorts we used the one-year contribution to lifetime risk, which is equivalent to 14 cancer cases per billion individuals per year. For the remaining pesticides that carry threshold hazards, we estimated risk by calculating dietary intake as a fraction of the EPA reference dose (U.S. Environmental Protection Agency, 1994).For these chemicals, we defined "negligible" as dietary intake less than the reference dose.

For each of the nine pesticides, we identified the major commodities contributing to dietary residue intake and the major geographic regions of use. Most of the pesticides that met our ad hoc criteria for investigation did so only because of dietary intake in very young children. For ease of exposition, we focus on risks to one-year-olds because their risks typically are greatest. The risks from captan and benomyl both come largely from apples, which contribute 45% of the captan dietary intake and 69% of the benomyl dietary intake for one-year-olds. Captan and benomyl are used in apple production mainly in the East and the Lake States; they are hardly used in the West. Most of the remainder of captan and benomyl dietary intake estimates come from imported food. Almost all U.S. bananas are imported, and 23% of the benomyl dietary intake comes from banana consumption. (This residue average was based on few detections.) Grape consumption accounts for 47% of the captan dietary intake; captan residues on imported grapes are at least 9 times greater than on domestic grapes.

Risks from dietary intake of dimethoate follow the same pattern as with captan and benomyl. Apples carry the largest proportion of dietary intake from dimethoate, which is used on apples primarily in the mid-Atlantic and Lake States (North Carolina, Virginia, Pennsylvania, New York, and Michigan). The other major source of dietary intake is grapes; imported grapes carry at least 3 times as much dimethoate as domestic production.

Dietary intake of the insecticide azinphos-methyl comes primarily from domestic on-farm use on apples. Apples are the major contributor to dietary intake for one-year-olds. Depending on the state, it is applied on 57 to 90% of apples, an average of 2.5-6.5 times. It is a major contributor to insect control on apples across the U.S, and is one of the few apple pesticides whose use varies only a little among regions.

Permethrin residues in the diet come from peaches, green beans, celery, and lettuce. It has little regional variation in use for any of these crops.

Other risks are largely due to region-specific pesticide use. Green beans are the source of the largest share of dietary intake of chlorothalonil. While green beans are produced across the U.S., chlorothalonil is important in green bean production only in the South: North Carolina (83% of beans), Georgia (76%), and Florida (44%). It is used on only 16% of beans in California and even less in other states outside the South.

We included acephate because one of its degradation products (methamidophos) met our risk criterion. For methamidophos, 59% of dietary intake comes from green bean consumption. Methamidophos is not registered for use on green beans and has no tolerance by itself. Thus, methamidophos residues probably result from acephate use. Acephate use on fresh green beans is important to production only in the South: 39% in Florida and 36% in Georgia.

Apples account for 93% of ethion residue intake (out of the 10 AMS commodities) for one-year-old children. Ethion use in Washington appears to be the dominant source of this intake; it is the only major apple-producing state with quantifiable ethion use. Even in Washington its use is rare, with 2% of apples treated an average of 1.2 times.

Of the pesticides where on-farm uses are a major source of dietary intake, most are crop and region specific. This suggests that research to develop alternatives could be focused narrowly. However, the most important risk is from two broad-spectrum fungicides, captan and benomyl, which have been in use for many years. At various times, both pesticides have been examined under EPA's Special Review, and several food use registrations of captan were canceled in 1989. Thus, the need to develop alternatives for these chemicals has been apparent, but few alternatives have emerged (Hickey, 1991). Before further public support is provided for research and development for alternatives to broad-spectrum fungicides, it would be useful to understand why past private and public efforts have not been successful.

Conclusions

Any research or regulatory initiative to reduce risks must first identify the sources of risk. Each pesticide is different in the extent to which various sources contribute to dietary intake and risk. Thus, without knowing the relative contribution of each source, government intervention intended to reduce risks could fail to address the largest sources of risks.

The Federal government has responded to the scientific community with programs intended to reduce dietary intake of pesticides. These programs focus on reducing current domestic, on-farm use. This focus may address some environmental concerns raised by pesticide use, but it misses most sources of dietary intake. Our results indicate that research or other efforts to reduce pesticide risk or pesticide use must also address canceled persistent chemicals, post-harvest pesticides, and residues on imported foods.

References

1. Eichers, T., R. Jenkins, and A. Fox. 1971. DDT used in farm production. Agric. Economic Rep. No. 158. Economic Research Service, U.S. Dept. of Agric., Washington, D.C.
2. Elkins, E.R. 1989. Effect of commercial processing on pesticide residues in selected fruits and vegetables. J. Assoc. Official Analytical Chemists 72:533–535.
3. Engler, R. 1993. List of chemicals evaluated for carcinogenic potential. Memorandum, August 31. Office of Prevention, Pesticides, and Toxic Substances, Environmental Protection Agency, Washington, D.C.
4. Gonzalez, A.R., D.R. Davis, E.R. Elkins, and E.S. Kim. 1989. Reduction of ethylenethiourea residues in canned spinach. HortScience 24:990–992.
5. Hickey, K.D. 1991. Fungicide benefits assessment, fruit and nut crops—East. National Agricultural Pesticide Impact Assessment Program, U.S. Dept. of Agriculture, Washington, D.C.
6. Kuchler, F., S. Lynch, S., K. Ralston, and L. Unnevehr. 1994. Changing pesticide policies. Choices 9(2):15–19.
7. Kuchler, F., and K. Ralston. 1994. Pesticide residues and food safety. In M. Anderson (ed). Agricultural Resource and Environmental Indicators. Agric. Handbook No. 705. Natural Resources and Environment Division, Economic Research Service, U.S. Dept. of Agric., Washington, D.C., pp. 102–105.
8. Kuchler, F., K. Ralston, L. Unnevehr, and R. Chandran. 1996. Pesticide residues: reducing dietary risks. Agric. Economic Rep. No. 728. Economic Research Service, U.S. Dept. of Agric., Washington, D.C.
9. Love, J. 1995. Specialty crops overview. U.S. Dept. of Agric. Agricultural Outlook, November 9–11.
10. National Research Council. 1987. Regulating Pesticides in Food: The Delaney Paradox. National Academy Press, Washington, D.C.
11. National Research Council. 1993. Pesticides in the Diets of Infants and Children. National Academy Press, Washington, D.C.
12. State of Florida. 1994. Official Rules Affecting the Florida Citrus Industry. Part 1, Rules of General Application. Dept. of Citrus, Lakeland, Florida, March 20.
13. U.S. Dept. of Agriculture. 1991. Nationwide food consumption survey 1987/8, public use data file. Human Nutrition Information Service, Washington, D.C.
14. U.S. Dept. of Agriculture. 1992. Agricultural Chemical Usage—1991 Fruits and Nuts Summary. AgCh1(92). National Agricultural Statistics Service and Economic Research Service, Washington, D.C.
15. U.S. Dept. of Agriculture. 1993. Agricultural Chemical Usage—Vegetables 1992 Summary. AgCh1(93). National Agricultural Statistics Service and Economic Research Service, Washington, D.C.
16. U.S. Dept. of Agriculture. 1994. Pesticide Data Program (PDP) Summary of 1992 Data. Agricultural Marketing Service, Washington, D.C.
17. U.S. Dept. of Agriculture. 1995. Fruit and Tree Nut Situation and Outlook. FTS-274. Economic Research Service, Washington, D.C., September.
18. U.S. Dept. of Health and Human Services. 1993. Food and Drug Administration Pesticide Program: Residue Monitoring, 1992. Food and Drug Administration, Washington, D.C.
19. U.S. Environmental Protection Agency. 1992. Exposure assessment guidelines. Federal Register 57:104:22915, May 29.
20. U.S. Environmental Protection Agency. 1994. Office of Pesticide Programs Reference Dose Tracking Report, Office of Pesticide Programs. Mimeo. April 18.
21. U.S. Environmental Protection Agency. 1995a. Prevention, pesticides and toxic substances. Pest Smart Update #3. EPA-733-N-95-002. Washington, D.C.
22. U.S. Environmental Protection Agency. 1995b. Prevention, pesticides and toxic substances. Partners for pesticide environmental stewardship. EPA-730-F-95-002. Washington, D.C.

USDA Commits to Sustainable Agriculture

The USDA recently announced a new agency-wide policy directive expressing the Department's commitment to sustainable agriculture, based on a Memorandum on Sustainable Development issued by USDA Secretary Dan Glickman. That memorandum supports sustainability throughout the Department's programs, and culminates the year-long work of the 50-member interagency Sustainable Agriculture Working Group, which examined barriers to adopting more sustainable farming methods. It also responds to recommendations from the President's Council on Sustainable Development. The Working Group identified 33 ways for the USDA to overcome barriers to sustainable agriculture.

Copies of "Toward a More Sustainable American Agriculture" are available from USDA/CSREES/Partnerships, Room 3868 South Building, 1400 Independence Ave., SW, Washington, D.C. 20250; (202) 720-5203.

Sustainable agriculture in the Corn Belt: Production-side progress and demand-side constraints

David R. Lighthall

Abstract. *This paper explores the constraints to sustainable agriculture in the Corn Belt stemming from the trend toward increased farm size and the continued dependence of the region on undifferentiated farm commodities produced for regional, national, and international markets. It is based on a three-county comparison of 14 full-time farmers who have embraced sustainable principles and practices, and a randomly sampled group of 25 farmers. An encouraging finding was the substantial progress made towards lower-input production of corn and soybeans by the nine farmers who had adopted the ridge tillage system, which uses elevated seedbeds, banded herbicides, and post-plant nitrogen application to reduce both soil erosion and synthetic chemical inputs while maintaining yields. However, operators of large farms that depend on hired labor and highly dispersed field sites regarded these practices as too risky at their scale of production despite their short-term economic and long-term environmental benefits. The region's commercial farmers appear split between family farmers who wish to avoid the headaches of scale expansion and hired labor, and therefore, embrace more efficient low-input systems such as ridge tillage versus those who reject the increased management intensity and risks of lower-input systems in favor of scale expansion via more chemical-intensive no-till systems. Although ridge tillage represents movement toward low-input cash grain production, low-input production systems alone are not sufficient to improve the underlying social welfare of rural areas. Arresting the trend towards fewer and larger farms will also require development of more specialized or more localized markets for sustainably produced commodities.*

Key words: low-input agriculture, ridge tillage, farm size, farm structure, market development, no-till

Introduction

A noteworthy aspect of the sustainable agriculture movement is its idealistic goal of redirecting change in rural regions toward improved resource conservation and social welfare. It confronts a globalized system of agriculture in which input production, food processing, and final consumption are dominated by multinational corporations (Goodman et al., 1987). In addition, the continuing increase in farm output from ever more powerful mechanical, chemical, biological, and information technologies has contributed to a continuing increase in the size of farms and a parallel reduction in the number of full-time farming households in the United States. In Iowa, for example, from 1940 to 1987 the number of farms declined by 51% and average farm size increased by 88% (U.S. Dept. of Commerce, 1940-1990). In light of this historical process and the current policy emphasis on further deregulation, what evidence is there to suggest that Corn Belt farmers will not continue to swallow up their neighbors via chemical-intensive production systems that threaten regional water quality and the health of farmers and farm workers?

The fortunes of most farm households in the region currently ride on their competitive production of undifferentiated commodities such as corn, soybeans, pork, and beef for regional, national, and international markets. The long-term trend in the value of these commodities is generally downward while prices of inputs have risen, creating pressure to expand the scale of farms. The vulnerability of the Corn Belt to this cost-price squeeze is exacerbated by the diminished market for high-value niche commodities because of low urbanization in the region. Can low-input agriculture gain roots and flourish in the face of such unfavorable regional conditions? How much of a contribution can low-input production systems make, and what other elements will be needed for such a transformation to occur? What kinds of practices are emerging as successful compromises between market forces and sustainability goals?

These questions were central in the design and execution of a study that compared conventional versus low-input farming operations in north central Iowa (Lighthall, 1993). The following observations serve as anchor points for the subsequent discussion of the study's findings. First, interregional research has underscored the need to place the relationship between farm structure and the adoption of low-input agriculture in a regional context (Bultena et al., 1995, pp. 68–70; Smolik et al., 1995). Given that the developmental characteristics and patterns of low-input agriculture vary significantly because of interregional differences in environmental conditions, labor and commodity markets, and the social organization of farming, each region has a different starting point and different obstacles to overcome. Taking suitable account of regional characteristics is central

David R. Lighthall is Assistant Professor, Department of Geography, Colgate University, 17 Persson Hall, Hamilton, NY 13346.

to formulating achievable objectives and supportive public policies. This study's conclusions are specific to the circumstances of corn and soybean production in the Corn Belt.

Second, at the micro scale of analysis, the structure of a given farm (defined by its size and corresponding social relations, such as its orientation towards family versus hired labor), is an important influence on the operator's acceptance or rejection of low-input agriculture. Low-chemical production of row crops typically depends on more ecologically integrated methods of fertilization and pest control (Stinner and House, 1987). As a result, field operations in low-input systems may require a higher level of management acuity and fieldwork precision. Under these conditions, the size of a farm and the kind of work force it uses will affect the feasibility of this new approach.

Third, economically viable low-input production technologies alone will not necessarily insure a transition to sustainable agriculture. Favorable marketing conditions for higher value and sustainably produced commodities are crucial as well. Although low-input practices may offer long-term resource conservation and health benefits, farmers also need and deserve more immediate economic rewards for taking extra efforts or risks to produce a better product with long-term benefits for society. Increasing the demand for high quality, sustainably produced food for local and regional markets represents the next frontier for sustainable agriculture, one that will require coordination among a wide range of institutions (Hassebrook and Bird, 1995, pp. 245–246).

In this paper I examine the evolution of low-input agriculture in a representative Corn Belt locale in order to explore and substantiate these contentions. The study was based on intensive interviews of low-input and conventional farmers about the history of their farms and farming practices, including their explanations for changes in capital investments, practices, and marketing. The results of these interviews will be used to shed light on what types of farms and farmers are embracing the principles and practices of sustainable agriculture in the region. The subsequent section lays a conceptual foundation for the research project, its findings, and the related issues raised above. Next, I discuss the empirical results of the Corn Belt research project, with emphasis on how farm size is related to farmers' receptiveness to the low-chemical system of ridge tillage. This is followed by a concluding discussion that applies these findings to the prospects for sustainable agriculture in the region.

Theoretical Approach and Research Methods

The conceptual framework, design, and objectives of the Ph.D. dissertation on which this paper is based reflected an overall goal of regional contextualization. An intensive examination of a representative study area was used as a window on the state of and prospects for low-input agriculture in the Corn Belt. A primary objective was to identify the forces that either encourage or impede farmers' adoption of lower-input practices and systems in a study area dominated by cash grain production.

In theory, the predominance of corn and soybean production over small grains, grassland, and livestock appears to preclude the possibilities for alternative agriculture as described by Batie and Taylor (1989), i.e., a holistic approach to production and social development based on integrated livestock and crop production with positive spin-offs for local communities. At best, one would expect some movement towards *low-input agriculture*, defined by these authors as production systems that seek reductions in petrochemical inputs with limited expected benefits for the broader social fabric of the region. Similarly, Gillespie (1995) uses the term *green productionist agriculture* for changes in synthetic chemical use driven largely by economic and environmental factors, as opposed to more comprehensive approaches to food production, processing, and consumption based on social welfare values and ecological principles. This distinction sets up a secondary issue addressed by this paper: Does the low-input innovation in the study area hold the promise of a longer-term evolution toward alternative agriculture? And if not, what barriers prevent it?

The project used an intensive, qualitative research design, limiting its investigation to 39 full-time farmers in Franklin, Grundy, and Hardin counties in north central Iowa. This area has rich, level soils with land values above the Corn Belt average. It is dominated by corn and soybean production. The farmers in the study fell into two groups. The first consisted of 25 farmers who were randomly sampled from the lists of owner-operators maintained by the USDA Agricultural Stabilization and Conservation Service (ASCS) offices in the three counties. All these participants were using some version of minimum tillage, but several were beginning to incorporate no-till production of soybeans. The two-year corn/soybean rotation was most common, but livestock and federal farm program considerations contributed to some continuous corn production.

In addition, I purposively sampled 14 low-input farmers, of whom 9 were from the membership list of Practical Farmers of Iowa (PFI), a leading organization of low-input farmers in Iowa, and the remainder from lists provided by county agricultural agency personnel. Nine of the 14 (all members of PFI) were using ridge tillage in a two-year corn/soybean rotation and three were incorporating low-chemical input practices with minimum tillage in a similar rotation; the two smallest operations in the study (33 and 101 ha) were run organically, with multicrop rotations and livestock. Of the eligible farmers contacted, 93% agreed to participate in a farm history interview.

In trying to discern why certain farmers were embracing lower-input practices and systems while others remained committed to conventional methods, the first step was to gain an understanding of how and why farming practices had evolved on individual farms. To this end, farm history interviews with each participant focused on changes over the course of their tenure in the following areas: major capital investments in land, equipment, and facilities; the amounts and kinds of crop and livestock production; land tenure arrangements; use of household and hired labor; changes in crop production methods and systems, especially fertilization and pest control practices; participation in federal commodity programs; on- and off-farm sources of income; and financial and marketing strategies. In short, I asked farmers what they did, when they did it, and why. The interviews also covered participants' perceptions of low-input agriculture, government programs, and agroenvironmental issues. The tape-recorded and transcribed farm history interviews generated large volumes of both qualitative and quantitative data (over 900 pages of transcript) that I categorized, condensed, and displayed for comparative analysis in a database management system.

This qualitative approach assumes that participants' explanations of changes on their farms are acceptably accurate for generalizing about forces that facilitate or constrain low-input agriculture in the study area and the region (Miles and Huberman, 1984). In addition, I specifically asked participants to explain why they did or did not use certain low-input farming practices. Once the evolution of production practices had been characterized for individual farms, the next objective of the comparative analysis was to identify farm-to-farm similarities in the causes and patterns of chemical use and adoption of production systems.

Farms can be classified into several structural categories that are important in both theoretical and practical terms. Though all commercial farms are capitalist in the sense that they must make a profit via market exchange, there are important structural differences in their size and social organization that can influence farming practices. The size and organizational attributes of the family farm exemplify petty capitalist social relations, i.e., most management and labor is done by household members, with little dependence on hired labor. Farmers who choose to expand their farms must find an outside labor source, usually through hiring part-time or full-time help. Interviews with participants in this study revealed that the decision to expand beyond the limits of the household work force is an important step that typically entails new management strategies, substantial equipment investments, and new sources of risk. This decision puts the farm into a new structural category that represents a synthesis of family farm and fully capitalist social relations. Although they now depend substantially on hired labor, most of the labor and management is still carried out by family members. I use the term *quasi-capitalist* to denote this intermediate category.

Considerably larger farming operations in the range 1000 to 2000 ha also can be found in the study area and elsewhere in the Corn Belt. These fit the model of the fully capitalist enterprise: fieldwork is done exclusively by hired workers, salaried farm managers oversee day-to-day management, and the owners act largely as investors or limit their management to major strategic decisions. The discussion to follow is couched largely in terms of farm size and its impact on farming practices, but the size of a farm is linked to the character of its work force and its organizational structure. .

The interviews showed that farm structure had an important influence on chemical use and adoption of low-input practices. As a result, farms in each group were placed into one of three farm structure categories based on similarities in production scales and social relations (land tenure and dependence on hired labor). To gauge the correspondence between farmers' explanations and their actual practices, I combined quantitative and qualitative data into composite indexes of chemical use intensity, crop rotation, and the level of hired labor.

The following decision rules were based on the range of participants' existing farming practices.

- *Chemical use intensity index*
  0.5 = organic (no synthetic chemical use)
  1.0 = 100% banding of herbicides, low N rates via side-dressing, and no insecticides
  2.0 = same as 1.0 except partial banding of herbicides
  3.0 = partial banding of herbicides, moderate N rates (no side-dressing), minor insecticide use
  4.0 = full broadcast herbicides, moderate N rates (no side-dressing), moderate insecticide use
  5.0 = no banded herbicides, high N rates, high reliance on insecticides.
- *Rotation index*
  1.0 = at least 20% in a third crop
  2.0 = a 50/50 rotation of corn and soybeans
  3.0 = 66% to 75% corn, the remainder soybeans
  4.0 = more than 75% corn but some soybeans
  5.0 = 100% corn.
- *Hired labor index*
  1.0 = no hired labor
  2.0 = less than 1 full-time worker in spring and fall
  3.0 = 1 full-time worker in spring and fall
  4.0 = more than 2 full-time in spring and fall or one full time worker
  5.0 = more than 1 full-time worker.

These indexes were then averaged for each of the three farm structure categories in the low-input and conventional groups to determine whether the empirical information on chemical use was consistent with the participants' emphasis on size as a explanation for chemical use practices.

Results and Discussion

Ridge tillage, farm structure, and low-input adoption

In this section I use the circumstances under which ridge tillage and associated low-input practices have diffused in the study area to illustrate the primary research findings. In turn, these results serve as the basis for a discussion of the forces that either impede or encourage low-input agriculture in the study area and the region. The information presented in Table 1 provides an introductory overview of the empirical differences in production methods in the 1990 cropping season between the two sample groups and the farm structure categories within each group.

The small family farm category, ranging from 33 to 162 ha, is composed of farms that are not at their full labor and management potential. Typically, they are run by younger farmers seeking to increase their land base or by older farmers who are scaling back as they approach retirement. These farms, therefore, have a lower level of capital investment and place fewer labor demands on the household. They rely on a higher proportion of off-farm income compared with the two larger categories. Medium-size family farms (190 to 322 ha) have expanded to the limits of their household labor and management capability. Because they hire little labor and do not depend heavily on off-farm income, they come closest to the idealized model of the family farm. In contrast, the large-scale, quasi-capitalist farms (364 to 869 ha) have expanded beyond the limits of their household labor force by hiring at least one full-time worker or two full-time seasonal workers.

Of particular interest here is the correspondence between increases in the scale of crop production and the levels of chemical use within each of the two samples (see Table 1). One way to explore the causes of this relationship is to look at how the low-chemical input system of ridge tillage differs from the more chemical-intensive systems of minimum tillage and no-till used by the conventional participants, and then examine what types of farm operations and farmers have either adopted or rejected the low-chemical approach. Ridge tillage had clearly become the main path toward lower-input row crop production in the

Table 1. Summary of key operational indicators by sample groups and farm structure categories.

	Conventional Operations (Random Sample)		
	Small Family (N=7)	Med. Family (N=13)	Quasi-Capitalist (N=5)
Average Size (ha)	142	223	504
Chemical use intensity (0.5–5 scale, 5 high)	2.71	3.38	3.80
Leased land (%)	47	54	91
Rotation index (1–5 scale, 5 high)	2.93	2.58	2.80
Age of operator	49	46.5	43.8
Labor index (1–5 scale, 5 high)	1.0	1.31	4.4
	Low-Input Operations (Purposive Sample)		
	Small Family (N=6)	Med. Family (N=7)	Quasi-Capitalist (N=1)
Average size (ha)	124	254	364
Chemical use intensity (0.5–5 scale, 5 high)	0.83	1.36	2.5
Leased land (%)	80	82	90
Rotation index (1–5 scale, 5 high)	1.67	2.21	3.0
Age of operator	41.8	47.1	40
Labor index (1–5 scale, 5 high)	1.29	1.29	5.0

study area. The analysis of ridge tillage in this study was based exclusively on its application by PFI members, most of whom were explicitly interested in the system's potential for minimizing dependence on synthetic chemicals. Proponents of ridge tillage make three claims with respect to sustainability that were largely corroborated by the testimony of participants in this study (see Beyn, 1982): 1) the system allows for significant reductions in herbicide use; 2) it is an excellent means of soil conservation; and 3) it results in higher profits per unit because of reduced input costs with no loss of yield.

An in-depth breakdown of ridge tillage helps to clarify how these goals are achieved. The 6- to 8-in. elevated seedbed (or ridge) is the core of the system. The harmful effect of plentiful crop residue on seedbed temperature and soil saturation is neutralized by the ridges' enhanced exposure to solar energy and improved drainage. This minimizes the risks of planting delays in rain-soaked fields or poorly drained soils. Second, removing the top several inches of the ridge by planter sweeps redirects weed seeds to the center of the row. Ridge-till participants consistently noted that weed pressure on their fields declined over time, a phenomenon also observed in a University of Minnesota study (Forcella and Lindstrom, 1988). Third, the benefits for soil erosion control and water infiltration are significant because of the combined effect of ample surface residue and contoured ridges. An eight-year Iowa study found an average soil loss of 1.1 t/ha on ridge-till plots, compared with 10.9 t/ha for plowed plots (Laflen et al., 1990). Fourth, drought risk is also reduced by the ability of ridge-tilled slopes to reduce surface runoff during intensive rainfall events. In sum, these elements mitigate yield losses from weed pressure, drought, planting delays, and heavy precipitation while yielding long-term improvements in topsoil retention and tilth.

The superior environmental and economic performance of ridge tillage also is related to its elevated seedbed and reduced chemical use. Because cultivation is necessary to rebuild the ridge for the next cropping season, the system encourages the banding of herbicides. Banding herbicides over the seedbed and using cultivation for the middle of the row reduces herbicide intensity by 50% with savings ranging from $25 to $50/ha. Progressive declines in weed pressure had led several of the ridge tillers to spot-spray herbicides in some fields and not spray at all in others, opening the possibility of pesticide-free production. (The ridge-tillers were using two-year rotations and did not use insecticide, e.g., to control corn rootworm.) Side-dressing of nitrogen (post-emergence application) also can be incorporated into the first cultivation pass. Because they coordinate fertilization with the growth cycle of the corn plant, ridge-till users reduced their N application rates by an average of 24% compared with applying pre-plant anhydrous ammonia. This lowered their costs and the potential for leaching losses before uptake. Some had begun to use the new late spring N test to spatially optimize application rates (see Magdoff, 1991). These changes in the efficiency of synthetic chemical use are complemented by the overall reduction in machinery costs by eliminating fall or spring chisel plowing.

Working through PFI and more informal local networks in the 1980s, ridge-till innovators successfully adapted this low-input system to the agroecological conditions of the study area. Those who had mastered the system and whose soils had made the three-to-four year transformation to a new status were achieving competitive yields with measurably lower input costs compared with both the predominant minimum tillage system and the newer, herbicide-intensive no-till systems. Some believed that this would enable them to survive without federal price supports, which they viewed as disproportionately benefiting large-scale, more chemical-intensive farms. This success, particularly where local soil conservation officials in Franklin County had set up on-farm ridge-till test plots for area farmers, had overcome some of the neighboring farmers' skepticism toward the system. Seven of the 20 conventional participants in the small and medium family farm categories expressed an interest in adopting the system or had sons or partners who wished to do so.

In contrast, all five large-scale, quasi-capitalist operators in the conventional category made it clear that they had no interest in ridge tillage, nor were they willing to incorporate side-dressing or banding into their current minimum tillage system. One had prior success with ridge tillage but abandoned

it when he and his father expanded their operation to over 800 ha in the 1980s. The one low-input operator in the large size category also had rejected ridge tillage but was using some side-dressing and banding.

What accounts for large farm operators' general resistance to a system that other local farmers had shown to be both feasible and profitable? A first step toward answering this question can be made by analyzing representative explanations offered by the farmers themselves as to the unacceptability of ridge tillage. A consistent theme of their analyses was the unacceptable risk posed by a system that depends on herbicide banding, mechanical cultivation, and post-emergence N application to achieve higher per acre profits:

> For the number of acres we got, I hate to rely solely on side-dressing because if we do start getting weather like this it can make it so you can't get any in.... See, right now we could go to banding all our herbicide, if we were pressed for that [via regulation] we could. Our biggest problem is if we get a real wet summer is to get them cultivated. (Franklin County, 854 ha)

> About four or five years ago [we banded herbicides] when things were all depressed, we were trying to cut the costs. About 1985 I would say.... That didn't work so bad, it seemed like it worked fairly well. We cultivated the centers then. But I didn't have as much acres to go over. (Hardin County, 688 ha)

> We have done some side-dressing, we did some in 1987 and 1988 and we have never found an advantage ... so we would rather do it in the spring. Our philosophy is when you are farming do all you can when you can—it comes out better. (Grundy County, 587 ha)

> Ridge-till is another technology that is very timely and, like I have said, sometimes with our hog operation [4,000 head annually] we can't be as timely. I have to hire some things done because of that, some spraying and this and that. (Hardin County, 502 ha)

In contrast, medium and small family farmers in the low-input group and, to a lesser extent, the conventional categories had adopted these techniques and were rewarded with higher profits per unit, particularly from banding herbicides. In other words, at some point beyond the scale of the family farm, the risks of low-input systems become unacceptable even though they hold the promise of greater efficiency and reduced environmental impacts.

Large-scale operations have difficulty completing the more timely and frequent ridge-till field operations in the available time. The basis for the greater efficiency of post-emergence application of N and banded herbicides is their closer synchronization with the growth cycles of crops and weeds: The idea is to wait until the weed comes up, then kill it with a combination of chemical and mechanical methods, and not to give N to the corn plant until it really needs it. The outcome of more closely integrating production methods with agroecological processes is twofold: less of the chemicals migrate beyond the soil profile to contaminate water supplies, and farmers reduce their input costs. Moving to an even higher level of agroecological integration, organic production of corn and soybeans typically requires the addition of at least one additional crop in rotation and even more frequent and timely field operations for weed control.

The point is that as farms expand, these "production windows" do not expand proportionally—they are fixed by nature. The result is a progressive increase in the risk of not completing field operations in time (Lighthall, 1993; Lighthall and Roberts, 1995). This is especially true for large farms whose aggressive land acquisition strategies often result in fields dispersed over 250 km^2 or more. Therefore, as farms increase in size, so do the logistical challenges of completing field operations in time, especially when equipment breakdowns or rain cause delays. Participants in the conventional sample often mentioned this problem as a reason for not applying post-emergence N fertilizer. For the quasi-capitalist farmers, resistance to low-chemical practices also was shown by their aversion to mechanical cultivation and banding herbicides. For these farmers, the benefit of increased size lies in their ability to farm more land with proportionally less machinery and labor. As a result, they logically seek the most powerful fertilization and pest control technologies available, i.e., those that minimize the frequency and labor requirements of field operations. These technologies, such as broad-spectrum, broadcast pesticides and preplant anhydrous ammonia, almost always involve agrichemicals that dominate or supplant natural processes as opposed to harnessing or reinforcing them.

Large-scale operations' reliance on minimum tillage or no-till, broadcast herbicides, and conventional N application meant that their production costs per unit were measurably higher than with ridge tillage. This conclusion was based on participants' own production cost estimates and was consistent with the estimates of individual field operations published by the Iowa Cooperative Extension Service (1990). Compared with smaller operations that make full use of low-chemical practices, the larger, more chemical-intensive farms do not achieve superior efficiency because of scale expansion. Instead, they compensate for their higher chemical and labor costs per unit by controlling more land and therefore producing a higher volume. One must also take into account the fact that the additional labor inputs demanded by ridge tillage in June for cultivation and side-dressing do not represent out-of-pocket expenses for full-time family farmers who do their own fieldwork. This is not true for larger farms that use hired workers.

The role of farmer characteristics

One observation was shared by all participants: the agricultural depression of the early- to mid-1980s placed a great deal of pressure on farmers to find new ways of farming that would help them survive the crisis. As summarized in Table 2, farm production strategies in the study area have since been heading in two divergent trajectories, with strongly contrasting implications for resource conservation and social welfare in the region. Moving down one path are the ridge tillers and organic farmers who, while at different points on the continuum toward sustainable agriculture, share a goal of higher profits at their current production scales through more sophisticated use of their own management skills, their time, their implements, and the forces of nature. Drawn in the opposite direction, large-scale farmers are simply doing what by now is familiar to them: If you can't make a living on a one square-mile section, then find the technical means and extra manpower to farm two sections. The preceding analysis made the case that once the structure of a farm is given, it will affect subsequent decisions regarding the adoption of low-input farming practices. But to explain why individual operations have or have not evolved away from the family farm structure, we also have to account for differences among farmers themselves. Since the environmental and

Table 2. Alternative production strategies.

Capital, Scale, and Chemical Intensification Strategy
Goal: Increase the total profit of the operation via scale expansion
Range of techniques employed:
• Acquire more land via an aggressive search for new leases or purchases
• Hire non-household labor
• Substitute chemical inputs for tillage (e.g., no-till)
• Invest in large-scale equipment
Input Minimization Strategy
Goal: Increase profits by improving efficiency at the current production scale
Range of techniques employed:
• Substitute management and mechanical inputs for chemicals (e.g., ridge tillage)
• Increase commodity diversity
• Intensify household labor utilization
• Integrate production technology with agroecological processes

cultural factors that characterized this study were nearly uniform, the contrasting innovation strategies adopted by participants emerged from the interaction between the prior material conditions of their farm, their experiences, and their ideologies and values.

Several generalizations drawn from the study provide more specific insights as to why farmers chose one path or another. Participants were more likely either to have adopted an input minimization strategy or to have a favorable perception of low-input agriculture if they shared some of the following elements: a strong desire to pass the family farm on to subsequent generations; a disdain for hiring farm workers or an attitude of perfectionism regarding farming practices; a heightened concern about soil erosion and the threats of chemical contamination to family and community; and an absence of partnerships that required collective decisions on innovations. Often these farmers had adopted this approach early in their tenure, reflecting the greater receptiveness of younger participants to low-input agriculture. This receptiveness in turn was related to their lower investments of money in conventional cropping systems, the lower amount of time spent in learning about them, their higher land costs, and their limited investment capital (Lighthall, 1995). In contrast, strategies of scale and chemical intensification were adopted by participants who shared some of the following characteristics: they had inherited large-scale operations; they felt a strong desire for above-average household income; they saw scale expansion and hired labor as legitimate and necessary strategies for farm survival; they were more inclined to relish the challenges of managing a larger operation; and they tended to discount the environmental impacts of large-scale, chemical-intensive production.

Implications for Sustainable Agriculture in the Corn Belt

In a negative sense these findings illustrate how the dual dimensions of unsustainability that plague Corn Belt agriculture have a common origin in the agrichemical revolution that began in the 1950s. Not only do synthetic chemicals and their mechanical counterparts continue to provide farmers with the means to absorb their neighbors' farms, they also can create a range of unintended environmental threats. On the positive side, the superior efficiency of ridge tillage is a compelling counterexample to the assumption that chemical-intensive production systems are widespread because they are more economically efficient.

This analysis of the structural differences in the timing and frequency of low-input versus conventional production operations provides a partial response, at least for corn and soybean production in the Corn Belt, to Bird and Johnson's (1995, p. 226) query as to whether there is a causal relationship between farm size and the adoption of sustainable practices. The difference in the capacity of medium-scale versus large-scale operations to adopt more efficient low-input methods of corn/soybean production indicates that a primary rationale for the adoption of high-chemical input systems is the need for heightened control over the forces of nature in the face of the cost-price squeeze rather than higher efficiency and profitability per unit. The inherent power of synthetic fertilizers and pesticides provides farmers with this control, leading to such signs of unsustainability as contaminated water supplies, elevated cancer rates among the farm population, and the displacement of farm households from agriculture. Therefore, the size and corresponding social organization of Corn Belt farming operations are inseparably related to farmers' choice between alternative paradigms of agroecological control.

It is encouraging that innovative farmers and farming organizations such as PFI can implement low-input systems such as ridge tillage. Its greater profitability and its ability to conserve soil and water should help family farms survive over the long-term by helping them retain their current land base in the face of land market competition, to expand that base if necessary to bring the next generation of the household into the ranks, and to insure that the farm's natural resources will be maintained for subsequent generations. Also, PFI as an organization and most of the ridge tillers interviewed for this study are not content with their current dependence on synthetic chemicals, particularly herbicides, and are engaged in research to find ways of further reducing chemical inputs. Several ridge-till participants were especially interested in the further development of markets that pay a premium for pesticide-free grains along the lines of Pioneer Hi-Bred International's "Better Life Grains" program. Even more significant premiums were available in the area for organically produced grains, but this was not viewed as an option for most ridge tillers because of their dependence on synthetic N and their current scales of production.

However, it is not clear that increasing profits per unit through more management-intensive production systems like ridge tillage can stem the forces that impel many farmers toward continued expansion. These findings may simply indicate a shift to low-input or "green productionist" agriculture by a modest fraction of farmers, a shift that is unlikely to evolve into the comprehensive vision of sustainable agriculture that includes an increase in the number of farms, a corresponding intensification of rural

economic and cultural interactions, and a resultant improvement in the quality of life for the rural population. Meeting these social sustainability objectives will most likely require the reintegration of agricultural production with the local economy as part of a broader decentralization in the agricultural input and the food processing, marketing, and consumption systems (Strange, 1988; Flora, 1990).

The response to this challenge goes back to a point raised at the beginning: Sustainable production systems clearly are essential to the development of sustainable agriculture, but they can only go so far without corresponding changes in the structure of agricultural commodity markets. As long as the focus of sustainable agriculture in the Corn Belt is producing mainstream commodities for regional, national, and international markets, it is hard to imagine a significant increase in the number of farm households with a more complex set of linkages to local business and markets. For this to occur, the low-input, cash grain ridge tilling currently diffusing in the study area would ultimately evolve into smaller scale, more labor-intensive systems based on multicrop rotations and livestock (for example, the one used by Richard and Sharon Thompson of Boone, Iowa, as described in National Research Council, 1989, pp. 308–323).

The success of PFI cooperators and others in developing lower-input farming methods in the study area and elsewhere in the Corn Belt is both commendable and essential. However, without specialized markets for agricultural commodities that allow consumers to discriminate on the basis of how the products were produced, there is limited economic incentive for the more labor-intensive, agroecologically integrated production of high-value commodities exemplified by the Thompson farm.

This situation is reminiscent of the recycling industry in the United States. The demand for recyclables languished for nearly 20 years until industry made the long-term investments needed to integrate non-virgin materials into their production processes. Once this demand-side development occurred, the market prices of recyclables took off, further spurring rates of waste recovery and use by industry (Young, 1995). In other words, for sustainable agriculture to reach the "takeoff" stage, it must go beyond simply being a slightly more efficient but more complicated way of producing undifferentiated commodities. Just as innovative farmers and their allies in the research institutions work to strengthen the production side of sustainable agriculture, other efforts must be directed towards nurturing the consumer's willingness to pay a reasonable premium for high quality food and insuring that markets exist for its expression.

Acknowledgments. The research on which this paper is based was supported by a grant from the Leopold Center for Sustainable Agriculture, Iowa State University. As Ph.D. dissertation advisor, Rebecca S. Roberts of the Department of Geography, University of Iowa, provided guidance in the design and execution of this project.

References

1. Batie, S., and D.B. Taylor. 1989. Widespread adoption of non-conventional agriculture: Profitability and impacts. Amer. J. Alternative Agric. 4:128–134.
2. Beyn, E.E. 1982. More Profit with Less Tillage. Beyn Enterprises, Boone, Iowa.
3. Bird, E.R., and B.J. Johnson. 1995. Future research needs. In E.R. Bird, G.L. Bultena, and J.C. Gardner (eds). Planting the Future: Developing an Agriculture that Sustains Land and Community, Iowa State Univ. Press, Ames. pp. 219–232.
4. Bultena, G.L., E.O. Hoiberg, and J. Dansingburg. 1995. Impact of sustainable farming on the structure of American agriculture. In E.R. Bird, G.L. Bultena, and J.C. Gardner (eds). Planting the Future: Developing an Agriculture that Sustains Land and Community, Iowa State Univ. Press, Ames. pp. 67–82.
5. Flora, C.B. 1990. Sustainability of agriculture and rural communities. In C.A. Francis, C.B. Flora, and L.D. King (eds). Sustainable Agriculture in Temperate Zones. John Wiley and Sons, Inc., New York, N.Y. pp. 343–359.
6. Forcella, F., and M. Lindstrom. 1988. Weed seed populations in ridge and conventional tillage. Weed Science 36:500–503.
7. Gillespie, G.W. 1995. Sustainable agriculture and prospects for rural community development in the U.S. Research in Rural Sociology and Development 6:167–191.
8. Goodman, D., B. Sorj, and J. Wilkinson. 1987. From Farming to Biotechnology: A Theory of Agro-Industrial Development. Basil Blackwell, Oxford, England.
9. Hassebrook, C., and E.R. Bird. 1995. Policy issues and recommendations. In E.R. Bird, G.L. Bultena, and J.C. Gardner (eds). Planting the Future: Developing an Agriculture that Sustains Land and Community. Iowa State Univ. Press, Ames. pp. 233–253.
10. Iowa Cooperative Extension Service. 1990. 1990 Iowa farm custom rate survey. Iowa Cooperative Extension Service, Iowa State Univ., Ames.
11. Laflen, J.M., R. Lal, and S.A. El-Swaify. 1990. Soil erosion and a sustainable agriculture. In C.A. Edwards, R. Lal, P. Madden, R.H. Miller, and G. House (eds). Sustainable Agricultural Systems. Soil and Water Conservation Society, Ankeny, Iowa. pp. 569–581.
12. Lighthall, D. R. 1993. Chemicals, class, and sustainable agriculture: A Corn Belt case study. Unpublished Ph.D. dissertation. Dept. of Geography, Univ. of Iowa, Iowa City.
13. Lighthall, D.R. 1995. Farm structure and chemical use in the Corn Belt. Rural Sociology 60:505–520.
14. Lighthall, D.R., and R.S. Roberts. 1995. Towards an alternative logic of technological change: Insights from Corn Belt agriculture. J. Rural Studies 11:319–334.
15. Magdoff, F. 1991. Managing nitrogen for sustainable corn systems: Problems and possibilities. Amer. J. Alternative Agriculture 6:3–8.
16. Miles, M., and A. Huberman. 1984. Qualitative Data Analysis. Sage Publications, Inc., Beverly Hills, California.
17. National Research Council. 1989. Alternative Agriculture. Board on Agriculture. National Academy Press, Washington D.C. pp. 308–323.
18. Smolik, J.D., T.L. Dobbs, and D. H. Rickerl. 1995. The relative sustainability of alternative, conventional, and reduced-till farming systems. Amer. J. Alternative Agric. 10:25–35.
19. Stinner, B., and House, G. 1987. Role of ecology in lower-input, sustainable agriculture: An introduction. Amer. J. Alternative Agric. 2:146–147.
20. Strange, M. 1988. Family Farming: A New Economic Vision. University of Nebraska Press, Lincoln, and Institute for Food and Development Policy, San Francisco, California.
21. U.S. Dept. of Commerce. 1940–1990. Census of Agriculture. Bureau of the Census. Washington, D.C.
22. Young, J. 1995. Recycling takes off in North America. World Watch 8(4): 20–25.

RESOURCES

"Direct Marketing Resource Notebook," produced by the Midwest Sustainable Agriculture Working Group, is $20 from Nebraska Sustainable Agriculture Society, P.O. Box 736, Hartington, NE 68739; (402) 254-2289. Nebraska residents should add 5% sales tax.

"Alternative Farming Systems—Economic Aspects, March 1993-June 1996," a bibliography, is available from Alternative Farming Systems Information Center, National Agricultural Library, 10301 Baltimore Ave., Room 304, Beltsville, MD 20705-2351; (301) 504-6559; e-mail afsic@nal.usda.gov; Internet—http://www.nal.usda.gov/afsic.

"New Partnerships for Sustainable Agriculture," 148 pages, is $14.95 plus $3.50 shipping from World Resources Institute Publications, P.O. Box 4852, Hampden Station, Baltimore, MD 21211; 1-800-822-0504 or (410) 516-6963; e-mail ChrisD@wri.org.

"Integrated Animal Waste Management," 87 pages, is $20 from Council for Agricultural Science and Technology, 4420 West Lincoln Way, Ames, IA 50014; 1-800-375-CAST.

"The Case of Organic Farming: Research Implications for a Paradigm Shift in Agriculture" is available for $20 from Centre for Resource and Environmental Studies, Australian National University, Canberra ACT 0200 Australia; phone (06) 249-4598; e-mail publications@cres.anu.edu.au; Internet— http://cres.anu.edu.au.

"Knee Deep in Grass," a study of 29 grazing operations published by the Minnesota Institute for Sustainable Agriculture, is $7 ($7.35 in Minnesota) for item BU-6693-NR from Minnesota Extension Service Distribution Center, 1-800-876-8636 or (612) 642-4900.

"Direct Marketing Resource Notebook" from the Midwest Sustainable Agriculture Working Group is $20 from the Nebraska Sustainable Agriculture Society, P.O. Box 736, Hartington, NE 68739; (402) 254-2289; Nebraska residents must add 5% sales tax.

"Beekeeping in Northern Climates," a manual and 40-minute video (EP-6684-NR), are $45 plus shipping and tax; manual alone (MI-6683-NR)is $15; the video (VH-6553-NR), $40; contact Minnesota Extension Service Distribution Center, 1-800-876-8636 or (612) 624-4900.

"IPMnet" is a free, global, collaborative, electronic Integrated Pest Management information source; for information, e-mail IMPnetNUZ@bcc.orst.edu.

"1996 CSA Farm Network" is $6 from Steve Gilman, Coordinator, CSA Farm Network, 130 Ruckytucks Farm, Stillwater, N.Y. 12170; (518) 583-4613.

"Organic Production: Recent Publications and Current Information Sources" is available from Alternative Farming Systems Information Center, National Agricultural Library, ARS, USDA, Room 304, 10301 Baltimore Ave., Beltsville, MD 20705-2351; (301) 504-6559; or on the Internet at http://www.nal.usda.gov.afsic

"Becoming Native to this Place," six essays by Wes Jackson, is available for $12.50 from Publishers Group West, P.O. Box 8843, Emeryville, CA 94662; 1-800-788-3123.

"Noah's Ark Today: Saving Rare Farm Animal Breeds from Extinction," a children's education program, contains a slide program, activities for K-6th grade, and a teacher's guide; each kit is $119 plus $11 shipping/handling from Carolyn Christman, American Livestock Breeds Conservancy, P.O. Box 477, Pittsboro, N.C. 27312; (919) 542-5704.

International Short Course on Agroecology will be offered at the Center for Biological Control at the University of California, Berkeley, June 16-25, 1997; for application, contact Dr. Miguel Altieri, University of California, 201 Wellman Hall-3112; Berkeley, CA 94720; e-mail agroeco3@nature.berkeley.edu; fax (510) 642-7428.

"Organic Agriculture Worldwide 1996–1997" is $16 from IFOAM, Okozentrum Imsbach, D-66636 Tholey-Theley/Germany; e-mail ifoam secretary@oln.comlink.apc.org.

Proceedings of the North American Symposium of the Association for Farming Systems Research/Extension, held in November, 1995, are $15, payable to NCRCRD, from Julie Stewart, North Central Regional Center for Rural Development, 404 East Hall, Iowa State University, Ames, IA 50011.

UPCOMING EVENTS

February 17–18, Great Lakes Grazing Conference will be held in Battle Creek, MI; contact Ben Bartlette, MSU Extension, U.P. Experiment Station, Box 168, Chatham, MI 49816-0160; (906) 439-5880.

February 18–20, New York State Farmers' Direct Marketing Conference and Trade Show will be held in Owego, N.Y.; contact Andrea Eichhorn, Conference Chair, (607) 862-3985.

February 18–21, "Sensors for Nondestructive Testing: Measuring the Quality of Fresh Fruits and Vegetables" will be held in Orlando, FL; contact Northeast Regional Agricultural Engineering Service, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, N.Y. 14853-5701; (607) 255-7654; e-mail NRAES@cornell.edu.

February 21–22, "Grow Better, Not Bigger," the Annual Meetings of the Nebraska Sustainable Agriculture Society and Nebraska Fruit and Vegetable Growers, will be held in Columbus, NE; contact NSAS, (402) 254-2289.

February 23–25, 14th annual California Farm Conference will be held in Riverside, CA; contact Mary Lou Weiss, University of California, (310) 781-7520; or UC Small Farm Center, (916) 752-8136.

February 24–25, "Charting a New Course," the Agricultural Outlook Forum '97 sponsored by the USDA, will be held in Washington, D.C.; contact USDA Graduate School, 600 Maryland Ave., SW, Room 142 (IH), Washington, D.C. 20024; (202) 401-9421.

February 27–March 2, Bio Fach '97, the World Organic Show, will be held in Frankfurt, Germany; contact Sunder & Rottner, Von-Vollmar-Str.4, D-91154 Roth; phone (+49) 09171/4011.

Inoculative release of anecic earthworms in a California orchard

Matthew R. Werner

Abstract. *Anecic earthworms (e.g., nightcrawlers) create deep, vertical burrows and feed by dragging organic matter from the soil surface into the burrow, thereby incorporating organic matter. The incorporation of leaf litter in orchards may reduce inoculum levels of organisms that cause diseases such as apple scab. However, anecic earthworms are generally absent from agroecosystems in California, in part possibly because of low rainfall and seasonal drought. Anecic earthworms (*Lumbricus terrestris*) were introduced to an organic apple orchard in Watsonville, California, where the resident earthworm community included only the endogeic (subsurface-feeding) species* Aporrectodea caliginosa *and* Microscolex dubius. *With* L. terrestris *present, incorporation of apple leaf litter increased from less than 28% to 79%. Yearly patterns of activity of resident earthworm species were unimodal, corresponding to the winter season of peak rainfall and low soil temperature. Earthworm populations were similar for organic and conventional treatments until the third year, when abundance and biomass of resident species were significantly greater in the organic plots.*

Key words: *Lumbricus terrestris, Aporrectodea caliginosa, Microscolex dubius*, organic farming, litter, apple scab, *Venturia inaequalis*

Introduction

Anecic earthworms such as *Lumbricus terrestris* (nightcrawlers) create deep, vertical burrows that form stable macropores for water infiltration, root penetration, and air exchange (Edwards et al., 1989). They feed by dragging organic matter from the soil surface into their burrows, thereby incorporating soil organic matter (Knollenberg et al., 1985). Large amounts of residues are stored underground in these burrows, where decomposition and mineralization is enhanced (Lee, 1985a). A laboratory study comparing soils with and without *Lumbricus terrestris* showed that nitrogen release from surface litter into the soil was three times greater with earthworms present (Binet and Trehen, 1992). Therefore, anecic earthworms may increase the availability to the crop of nutrients contained in surface organic materials such as crop residues, mowed weeds, and applied organic amendments.

Litter incorporation by anecic earthworms may reduce inoculum levels of certain plant pathogens, such as *Phytophthora syringae*, which causes fruit rot (Harris, 1979), and *Venturia inaequalis*, which causes apple scab (Raw, 1962). *Venturia inaequalis* overwinters on leaf litter and is transmitted to new foliage during spring rains (Hirst and Stedman, 1962). If leaf litter is incorporated into the soil before budbreak, inoculum levels will be reduced.

Although litter-incorporating species are common components of the earthworm fauna in temperate-climate agroecosystems (Werner and Dindal, 1990), they are uncommon in California. Among earthworms collected from orchards in Merced County, the most widely-distributed species was *Aporrectodea caliginosa*, an endogeic species (one that burrows and feeds primarily in the subsurface, mineral soil horizons). The epigeic (surface feeding) species *L. rubellus* and endogeic species *Amynthas diffringens* and *Microscolex dubius* were less common (Bugg, 1994). No anecic earthworms were collected, nor were obvious middens seen at any of the collection sites. Likewise, in earthworm samples from a variety of California agroecosystems, endogeic species were dominant, epigeic species rare, and anecic earthworms absent (Werner, 1993).

It is striking that the most common earthworms in California agroecosystems are peregrine (wandering) species, which are uniquely adapted for survival when transported by humans to new locations (Lee, 1985b). These include European Lumbricidae and South American and Asian Megascolecidae (Werner, 1993; Werner, personal observation). Native Californian megascolecids are almost invariably absent in agricultural soils, probably because they cannot tolerate disturbance.

Although considered a peregrine earthworm that is subject to wide dispersal and inadvertent colonization by humans (Lee, 1985a), *L. terrestris* typically is absent from California orchards. This may be due to a combination of factors:

- *L. terrestris* does not have seasonal dormancy that might otherwise allow it to survive inclement conditions, as do other peregrine earthworm species.
- Unlike most other peregrine earthworms, *L. terrestris* constructs deep, permanent burrows. These require about six weeks for construction under optimal conditions, and are subject to damage by tillage implements, which have been commonly used in California orchards.
- The California climate in typical production regions is characterized by summer drought and low annual precipitation. These are generally unfavorable for *L. terrestris*, and mean that it cannot persist on unirrigated agricultural field margins or recolonize disturbed agricultural

Matthew R. Werner is a Soil Ecology Specialist, Center for Agroecology and Sustainable Food Systems, 1156 High Street, University of California, Santa Cruz, CA 95064; werner@zzyx.ucsc.edu

environments from these areas. In contrast, *L. terrestris* is very abundant in orchards and pastures of Oregon's Willamette Valley and in other areas of the Pacific Northwest with greater rainfall (Fender, 1985; Werner, personal observation).

- Most California orchards have been subjected to herbicides and tillage, reducing the supply of plant residues on the soil surface for anecic earthworms.
- Many California orchards have been subjected to heavy applications of fumigants, fungicides, and insecticides, some of which are very deleterious to surface-foraging earthworms like *L. terrestris*.
- *L. terrestris* is an obligately sexual organism, unlike some peregrine earthworms (e.g., *A. caliginosa*). This means that to establish a viable population, at least two individuals must become established near each other. Given the above factors, this is unlikely.

My original objective in this study was to compare the abundance and biomass of resident earthworm species under organic and conventional apple orchard management, and to relate the results to management and weather. Because observed litter incorporation rates were low, and because anecic (litter-incorporating) species were absent from the initial samples, my second objective was to release anecic earthworms inoculatively and test their effect on litter incorporation and their ability to establish a population in the organic orchard.

Materials and Methods

This study was part of a whole-system comparison of conventional and organic apple production (Swezey et al., 1994). In April 1989 the experimental plots were established in randomized complete blocks with treatments corresponding to conventional and organic production system (designated simply "conventional" and "organic"). The plots were in a commercial, high-density, semi-dwarf (M-106) 'Granny Smith' apple planting on a 12.6-ha farm, 8 km west of Watsonville, California (Fig. 1). Each treatment was replicated three times in 0.32-ha plots. All trees were planted in 1982 in double rows (0.91-m offset) with trees spaced 1.8 m apart in the row and 1.2 m apart between rows. A tractor aisle with a mowed cover of resident vegetation was maintained between the double rows on 4.3 m centers. The first year of transition to organic management was 1989, and organic certification was obtained for the 1990 and 1991 crop seasons (California Certified Organic Farmers, 1990). The soil type is Elder sandy loam (coarse-loamy, mixed, thermic Cumulic Haploxeroll) in the western portion of the orchard, grading to Conejo loam (fine-loamy, mixed, thermic Pachic Haploxeroll) in the eastern portion.

The grower-cooperator was responsible for implementation of all certified organic and conventional management in the appropriate plots. Table 1 summarizes the production system treatments each year. All plots were irrigated with 100 mm of well water from ground sprinklers three times yearly, for a total of 300 mm/yr.

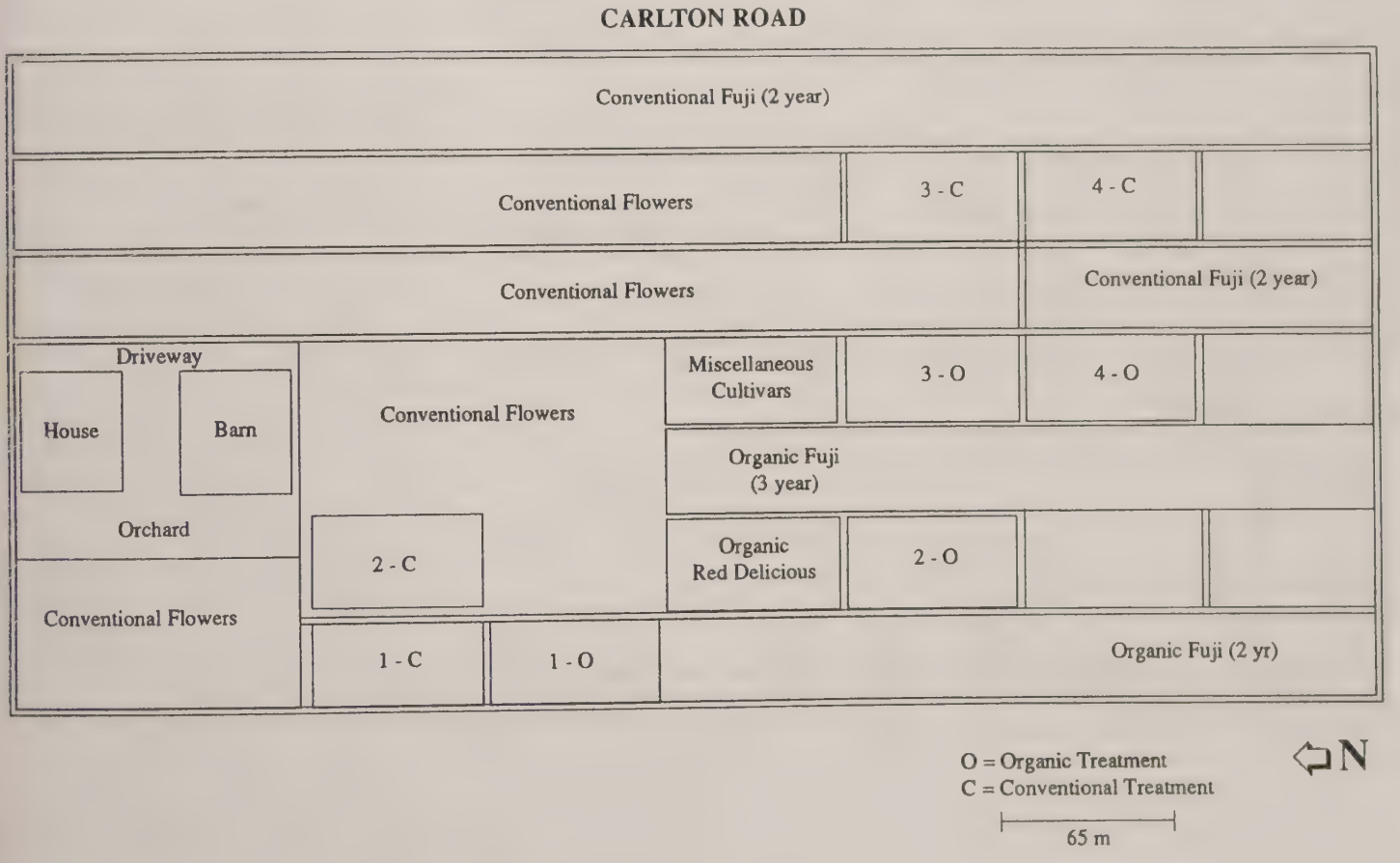


Figure 1. Granny Smith apple conversion study site. Watsonville, CA, 1989–1991.

Table 1. Production systems treatment summary, Rider Orchard conversion study, Watsonville, California.

Month	Management Procedure	
	Conventional	Organic
January	dormant oil + insecticide spray (chlorpyrifos)	dormant oil spray
February	tree row herbicide spray (glyphosate) calcium nitrate application	
March	lime sulfur fungicide spray sulfur fungicide spray tree row herbicide spray (glyphosate) mow aisle groundcover rodent baiting (phostoxin pellets) snail baiting (metaldehyde 4%)	oil-lime sulfur fungicide spray sulfur fungicide spray (3) rodent trapping mow aisle groundcover
May	thinning spray (carbaryl) irrigation codling moth spray (chlorpyrifos)	hand thinning/snail removal irrigation chicken manure compost application tree row weed cutting calcium phosphate rock soil application (1990) codling moth granulosis virus (CMGV) application (3) 1989–1990 codling moth mating disruption codlemone application (1991)
June	mow aisle groundcover foliar calcium nitrate application	
July	codling moth spray (chlorpyrifos)	CMGV applications (4) 1989–1990
	mow aisle groundcover irrigation foliar calcium nitrate application	mow aisle groundcover irrigation codling moth mating disruption codlemone application (1991)
August	mow aisle groundcover foliar calcium nitrate application	
September	irrigation mow aisle groundcover	irrigation
October	harvest zinc sulfate application (1990)	harvest zinc sulfate application (1990)
November		chicken manure compost application

Earthworm abundance and biomass

To compare resident earthworm communities under organic and conventional production practices, I sampled earthworms using the formalin expulsion technique (Satchell, 1971). Because this technique does not capture inactive individuals, its results are considered an estimate of relative earthworm activity. Each sample area was 0.25 m^2, and two samples were collected in the row and aisle areas of each plot. Two applications of 4.5 liters of a 0.18% formalin solution were made, with 10 minutes between each application. After all earthworms that surfaced were collected, the top 5 cm of soil was hand-sorted for additional earthworms. Samples were returned to the laboratory in a cooler for identification, counting and weighing. Weights were taken on live earthworms rinsed and blotted dry 24 hrs after collection to allow for gut voiding. Samples were collected in January 1990, monthly between December 1990 and May 1991, and in January and April 1992.

Inoculative release and apple litter incorporation

To measure the incorporation rates of known quantities of litter, apple leaves collected from the trees during leaf-drop were dried on a greenhouse bench and placed under litter frames in the orchard. The wooden frames covered 0.25 m^2 and were 3 cm high with chicken wire mounted across the top. I placed 90 g of dry apple leaves under each frame. Frames set out in February 1990 (six per treatment) were retrieved in April 1990, and litter remaining on the soil surface was collected, dried, and weighed. Twice as many frames were set out in January 1991, with half collected in April 1991 (six per treatment) and the rest collected in May 1991 (six per treatment). A split-plot design was instituted in the organic plots in January 1991. Half the litter frames in the organic plots received an inoculation of the earthworm species *L. terrestris* at the rate of 40 sexually mature adults per frame (equivalent to 160/m^2). The earthworms were obtained from a local fishing-bait dealer, and were harvested somewhere in the Pacific Northwest. Because this experiment was conducted on a commercial farm, my experimental design was influenced by consultation with the grower-cooperator. I did not use inoculative release of *L. terrestris* as a treatment in the conventional production system because it is a practice that conventionally oriented orchard managers are less likely to adopt.

Data on rainfall and soil temperature (15-cm depth) were collected from an automated California Department of Water Resources weather station in Watsonville. Data were subject to a two-way ANOVA with treatment and block as the group variables. I report statistical significance levels of 0.05 or lower.

Results

Earthworm abundance and biomass

Initially, two species of earthworm, *Aporrectodea caliginosa* and *Microscolex dubius*,

were resident in both production systems. *Lumbricus terrestris* was retrieved from organic plots in 1992, following introduction in the previous year. Peak activity of the resident earthworm species occurred between January and April, 1991. Statistically significant treatment differences in earthworm density and biomass (Figs. 2 and 3) occurred in the tree rows in January and April, 1992. Abundance and biomass generally followed similar trends in the tractor aisle area (data not shown). No earthworms were retrieved from conventional plots during the April 1992 sampling.

Apple litter incorporation

In 1990, apple litter incorporation for a two-month period averaged only 20% in both production systems. In 1991, *L. terrestris* increased incorporation to 79% of the apple litter in the subplots where it had been introduced (Figure 4). Less than 28% incorporation occurred in organic and conventional plots without *L. terrestris*.

Discussion

Sampling of the resident earthworm community and results of the litter incorporation study in 1990 established that no anecic species were present and that incorporation rates were low in both production systems. Studies of apple orchards in Europe have shown a correlation between earthworm biomass and the rate of loss of apple leaf litter from the soil surface when anecic species are present (Raw, 1962). The resident earthworm species at the study site *(A. caliginosa* and *M. dubius)* are endogeics, although *A. caliginosa* also feeds occasionally on the surface (Lee, 1985a).

To promote leaf-litter incorporation experimentally during the second year, I introduced *L. terrestris* to test its effect on litter incorporation and its ability to establish a population in the organic apple production system. This species is described as an anecic earthworm because it builds permanent vertical burrows and feeds by dragging organic materials from the surface into its burrows (Lee, 1985a). Daly et al. (1991) estimated that *L. terrestris* buried about 20 apple leaves per season per individual in an organic orchard in New Zealand. They estimated that a population of 20/m^2 would be required to bury the entire leaf fall in the observed orchard. I also found that

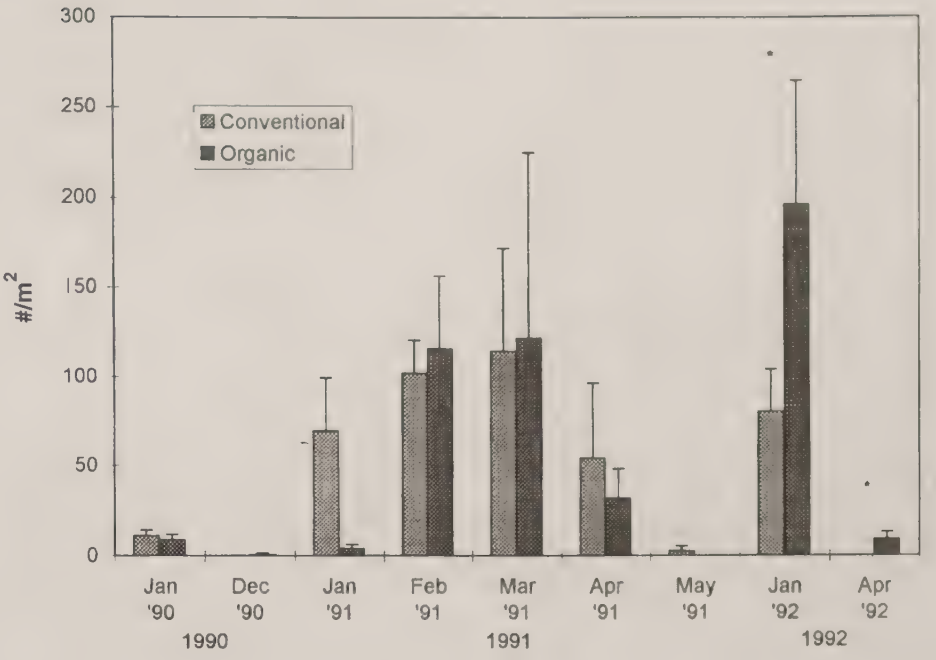


Figure 2. Resident earthworm abundance in tree rows at Rider Orchard during 1990–1992, estimated using formalin expulsion technique. Error bars represent standard error of the population. Note that X axis is non-continuous. Asterisks indicate statistically significant treatment differences for that sample date based on 2-way ANOVA results ($\alpha < 0.05$).

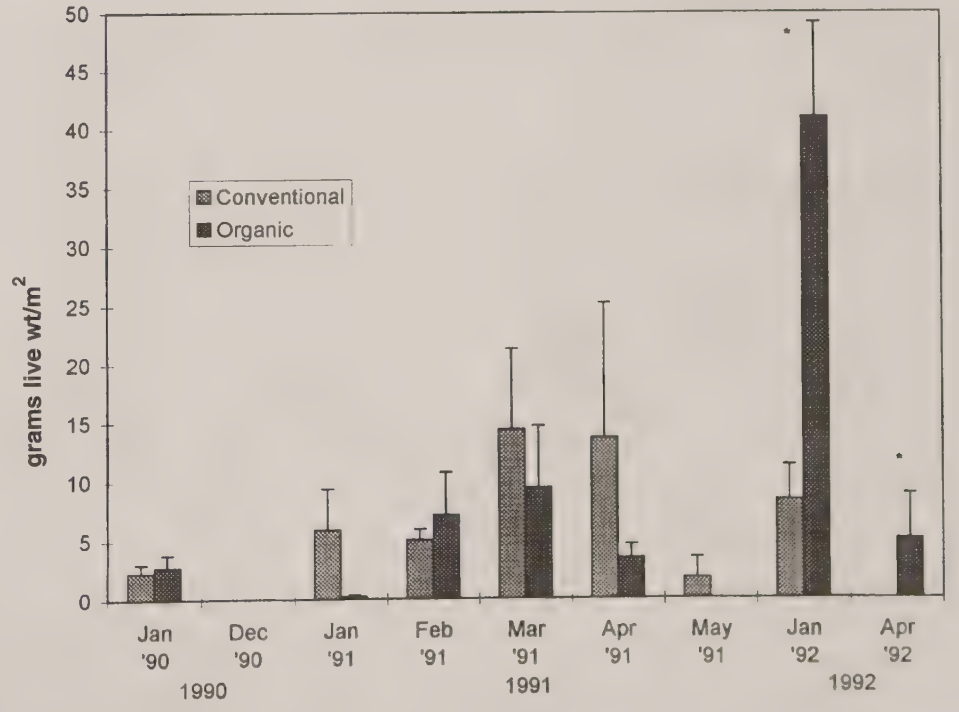


Figure 3. Resident earthworm biomass (live wt.) in tree row area of Rider Orchard 1990–1992. Error bars represent standard error of population. Note that X axis is non-continuous. Asterisks indicate statistically significant treatment differences for that sample date, based on 2-way ANOVA results ($\alpha < 0.05$).

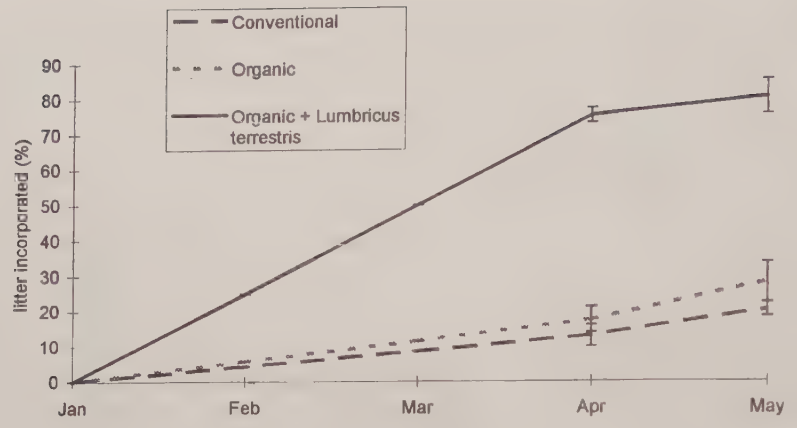


Figure 4. Incorporation of apple leaf litter in Rider Orchard (mean ± S.E.) during 1991. Known quantities of litter were placed under wire frames in January. Remaining litter under half of the frames was collected in April, and the final samples collected in May. Percent litter incorporated was significantly greater in the organic *L. terrestris* treatment during April and May, relative to the other two treatments.

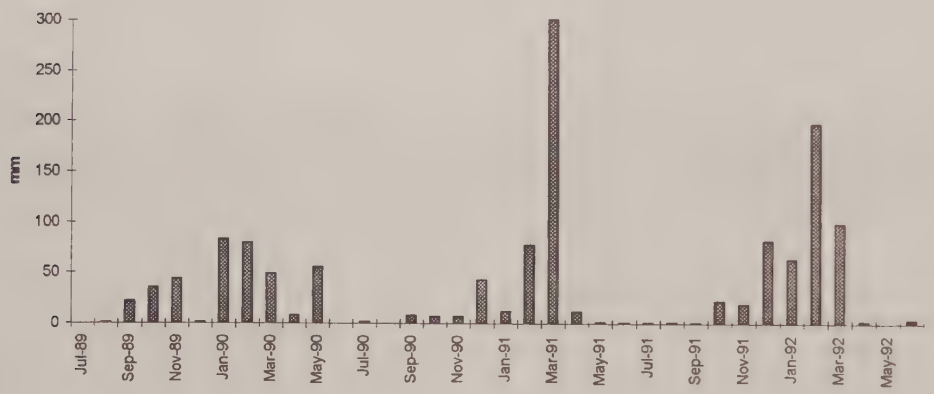


Figure 5. Monthly rainfall totals for 1989–92. Watsonville, CA.

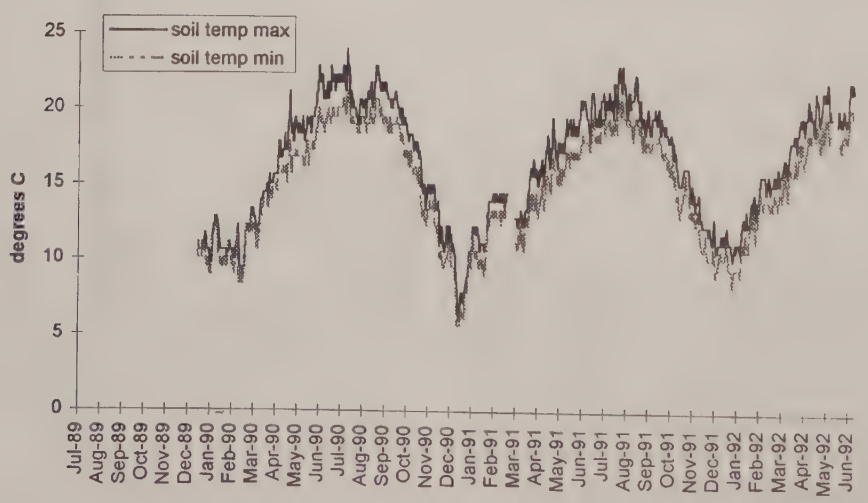


Figure 6. Daily maximum and minimum soil temperatures (15 cm depth) from an automated weather station located near the study site, Watsonville, CA.

L. terrestris significantly increased the amount of litter incorporated in spring 1991.

In both years that litter incorporation was measured, there were no significant differences between organic and conventional plots where *L. terrestris* was not present. This was due to the absence of any litter-incorporating species in either area. Three years of certified organic production practices did not appreciably alter the decomposition dynamics of surface-deposited leaf litter.

Resident earthworm activity patterns in the orchard corresponded to rainfall patterns. The climate of California's central coast is characterized by warm, dry summers and mild, wet winters, with rainfall concentrated during November to April. Mean annual precipitation is 76 cm and mean annual temperature is 12–14°C. Monthly earthworm samples from December 1990 to May 1991 showed peak activity during February and March. Rainfall during the 1990–1991 winter was below average and was concentrated in March (Fig. 5). Rainfall during the subsequent winter was closer to normal in amount, with peak distribution during November to March. Unlike regions with freezing winters, where earthworms have separate fall and spring peaks of activity, earthworm activity in central California appears to be unimodal, and concentrated during the coldest and wettest months. This is because the soil temperature remains above freezing during the winter rainy season (Fig. 6).

Earthworm densities close to 200/m^2 in organic tree rows were nearly 2.5 times greater than those seen in the conventional tree row areas in January 1992. Earthworms may have been responding to the cumulative effects of fertility and weed management practices in the organic production system. Additions of composted manure to the organic plots provided a potential food resource for earthworms. Weed growth was greater in the organic plots (Swezey et al., 1994), providing additional organic matter and altering the soil habitat by shading the surface. Pesticide use in the conventional production system may have reduced resident earthworm populations in those plots. For instance, Potter et al. (1990) showed that chlorpyrifos and carbaryl reduced earthworm biomass by about 30 and 70%, respectively, in a turfgrass system. Both compounds were applied in the conventional plots during this study.

Earthworm numbers increased because of the conversion to an organic production system, not from the inoculative release of *L. terrestris*. Earthworm samples were collected away from the *L. terrestris* release spots. In the January 1992 samples, 1 of 197 earthworms collected from organic tree rows was *L. terrestris* (0.5%), which accounted for 3.2% of the biomass. In the April 1992 samples, 1 of 10 earthworms collected was *L. terrestris*, accounting for 25% of biomass. These two individuals apparently migrated from the release spots. On the final sample date, no earthworms were found in the conventional production system plots.

Earthworms did not seem to be sensitive indicators of short-term ecological responses to the transition to organic management, as no significant treatment differences were seen during 1990-91. However, earthworm abundance and biomass increased significantly during 1992 in the organic plots and seemed to indicate a long-term response to changes in weed, pest, and soil fertility management. Although the litter incorporation study was not repeated in 1992, signs of surface deposition of casts and incorporated litter in January showed that *L. terrestris* was still active. Formalin expulsion samples over inoculation spots yielded both adults and juveniles. Because only adult *L. terrestris* were released during the previous winter, this shows that reproduction had occurred. One adult was found 10 m from the nearest inoculation spot, demonstrating the potential for dispersal of the species throughout the orchard. The inoculative release of *L. terrestris* increased the functional and specific diversity of the earthworm fauna in the organic production system.

I consider inoculative release to have the most potential to benefit organic or low-input orchards where anecic earthworms initially are absent and where minimal soil cultivation is practiced, especially during the winter, when earthworms are most active. Further studies are planned to determine if it would be more effective and more economical to release immatures instead of adults. Immatures are less expensive and may be more tolerant of being handled and introduced to new environments. Inoculative release may also have applications in conventional production systems, although the deleterious effect of certain pesticides and fertilizers on earthworms would have to be taken into account.

Acknowledgment. This work was funded by a grant from the University of California—Sustainable Agriculture Research and Education Program to S.L. Swezey and M.R. Werner. Amparo Nubia-Cardenas, John Fisk, Lynn Wunderlich, Josh Fodor, and Dmitria Sokolow helped with field work. Sam James determined the species. Some of the ideas in this manuscript are attributable to stimulating discussions with my colleague, Robert L. Bugg. Constructive criticisms were provided by S.H. Gage, M.S. Clark, and an anonymous reviewer.

References

1. Binet, F., and P. Trehen. 1992. Experimental microcosm study of the role of *Lumbricus terrestris* (Oligochaeta: Lumbricidae) on nitrogen dynamics in cultivated soils. Soil Biology and Biochemistry 24:1501–1506.
2. Bugg. R.L. 1994. Earthworm update. Sustainable Agriculture/Technical Reviews, U.C. Sustainable Agriculture Research and Education Program 6(3): 11–13.
3. California Certified Organic Farmers. 1990. Certification Handbook. Santa Cruz, California.
4. Daly, M.J., R.M. Beresford, M. Spink, E.P. Lorosy, J. Springett, and R. Gray. 1991. Management strategies for hastening leaf litter disappearance in organic apple orchards. Annual Report, Ministry of Agriculture and Fisheries, Agroecology Program, Palmerston North, New Zealand. pp. 22–24.
5. Edwards, W.M., M.J. Shipitalo, L.B. Owens, and L.D. Norton. 1989. Water and nitrate movement in earthworm burrows within long-term no-till cornfields. J. Soil and Water Conservation 44:240–243.
6. Fender, W.M. 1985. Earthworms of the Western United States. Part I. Lumbricidae. Megadrilogica 4:93–129.
7. Harris, D.C. 1979. The occurrence of *Phytophthora syringae* in fallen apple leaves. Annals of Applied Biology 91:309–312.
8. Hirst, J.M., and O.J. Stedman 1962. The epidemiology of apple scab. III. The supply of ascospores. Annals of Applied Biology 50:551–567.
9. Knollenberg, W.G., R.W. Merritt, and D.L. Lawson. 1985. Consumption of leaf litter by *Lumbricus terrestris* (Oligochaeta) on a Michigan woodland floodplain. American Midland Naturalist 113(1):1–6.
10. Lee, K.E. 1985a. Earthworms: Their Ecology and Relationships with Soils and Land Use. Academic Press, Sydney. Australia.
11. Lee, K.E. 1985b. Peregrine species of earthworms. In A.M. Bonvicini Pagliai and P. Omodeo (eds). On Earthworms. Selected Symposia and Monographs, 2 Collani U.Z.I. Mucchi Editore, Modena, Italy. pp. 315–327.
12. Potter, D.A., M.C. Buxton, C.T. Redmond, C.G. Patterson, and A.J. Powell. 1990. Toxicity of pesticides to earthworms (Oligochaeta: Lumbricidae) and effect on thatch degradation in Kentucky bluegrass turf. J. Economic Entomology 83:2362–2369.
13. Raw, F. 1962. Studies of earthworm populations in orchards. I. Leaf burial in orchards. Annals of Applied Biology 50:389–404.
14. Satchell, J.E. 1971. Earthworms. In J. Phillipson (ed). Methods of Study in Quantitative Soil Ecology: Population, Production and Energy Flow. IBP Handbook No. 18. Blackwell Sci. Pub., Oxford, England. pp.107–127.
15. Swezey, S.L., J. Rider, M.R. Werner, M. Buchanan, J. Allison, and S.R. Gliessman. 1994. Granny Smith conversions to organic show early success. California Agriculture 48(6):36–44.
16. Werner, M.R. 1993. Earthworms in California agroecosystems. Proceedings, Sustainable Soil Management Symposium, Univ. of California, Davis. pp. 53–63.
17. Werner, M.R., and D.L. Dindal. 1990. Earthworm community dynamics in conventional and low-input agroecosystems. Revue d'Ecologie et de Biologie du Sol 26:427–437.

Consumers Union Recommends IPM

Because the risks and costs imposed by pesticides on society are "unacceptably high and getting higher," Consumers Union has released a two-year study authored by Dr. Charles M. Benbrook that recommends "a program to reduce public health and environmental risks from pesticides at least 75 percent by the year 2020" through Integrated Pest Management (IPM). "Pest Management at the Crossroads" is $35.95 from Professional Mailing and Distribution Services Inc., P.O. Box 2013, Annapolis Junction, MD 20701; (301) 617-7815; e-mail pmac@pmds.com.

Green manure as a nitrogen source for wheat in the southeastern United States

Julia B. Nelson and Larry D. King

Abstract. *Interest in developing more sustainable cropping systems has led to renewed interest in legumes as N sources for crops. We conducted a 2-year study to compare the effects of green manure, green manure plus fertilizer, and fertilizer on wheat yield and N leaching potential. In 1991–92, wheat following corn and receiving 0, 45, or 90 kg N/ha was compared with wheat planted after plowing the autumn regrowth of red clover/johnsongrass hay (supplemented with alfalfa) that supplied 107 kg total N/ha. In 1992–93, wheat following corn and receiving 90 kg N/ha was compared with wheat following hay regrowth that either received fertilizer N at 45 kg/ha or 90 kg N/ha or was supplemented with alfalfa (total of 123 kg N/ha). Yield with only green manure averaged 65% of yield with 90 kg N/ha. Yields with green manure plus 45 or 90 kg N/ha were not different from yield with 90 kg N only. The first year, soil NO_3^-–N to a depth of 30 cm declined from as high as 40 kg/ha in the fall to less than 10 kg/ha as wheat growth increased in the spring. In contrast, NH_4^+–N concentration averaged 20 kg/ha throughout the growing season. Trends in soil inorganic N were similar the second year. Profile nitrate distribution indicated a greater potential for N leaching with fertilizer than with green manure. Soil from the site was used in a laboratory incubation study to determine the rate of N mineralization from white clover at 10°C. An average of 80% of the clover N was recovered as soil inorganic N; however, in the field study, recovery (soil inorganic N in the 0 to 30-cm zone + N in above-ground wheat biomass) was only 21%. Supplementing green manures with spring applications of fertilizer N could decrease the leaching loss without decreasing wheat yield.*

Key words: nitrate leaching, crop rotations

Introduction

Legumes have been used as a source of N for subsequent crops for thousands of years. Recent interest in developing more sustainable cropping systems has revived interest in legumes. In contrast to the study reported here, most studies involving legume-derived N for wheat *(Triticum aestivum)* have been conducted in areas where the legume can be grown only during the previous wheat growing season because the off season is too dry or too cold. In Australia, Reeves et al. (1984) found yields were 26% higher in a 2-year rotation of lupine *(Lupinus angustifolius)* and winter wheat than in continuous wheat. No fertilizer N was used in either treatment. In another Australian study, Doyle et al. (1988) found yields were 55 to 145% higher with lupine-winter wheat than with continuous wheat when no N fertilizer was used. Wheat yields after lupine were equivalent to yields of continuous wheat receiving 40 kg N/ha. In a third Australian study, Strong et al. (1986) followed one year of grain legumes with two years of wheat. Four of the eight legumes grown before wheat resulted in yields 17 to 23% higher than the maximum yield of continuous wheat receiving fertilizer N (50 kg N/ha).

In North Dakota, Badaruddin and Meyer (1990) grew several legumes during the summer, incorporated them in the autumn, and grew wheat the following summer. In only two of 20 combinations of legume, year and location did yield of wheat following legumes exceed yields of wheat following summer fallow and receiving no fertilizer N. In a 24-year study in Saskatchewan, Zentner et al. (1987) found that wheat yield after 3 years of bromegrass (*Bromus inermis*)/alfalfa *(Medicago sativa)* hay and one year of fallow averaged 14% higher than yield of wheat alternating with fallow and receiving N fertilizer. Wheat yield following one year of sweet clover *(Melilotus alba)* was only 4% higher than in the fallow-wheat treatment.

In a field experiment involving three sites in South Australia, Ladd et al. (1981) incorporated ^{15}N-labeled medic *(Medicago littoralis)* into the top 10 cm of soil. Uptake of the applied N by wheat planted 8 months later was 11-17%, which was 4-10% of the N in the wheat at harvest. In another field study with labeled medic, urea, ammonium sulfate and potassium nitrate, Ladd and Amato (1986) found that 17% of N applied in medic was in the tops of the wheat, with 62% remaining in organic residues in the soil. Eight months after incorporation, 18% of medic N was present as inorganic N in the top 90 cm of soil. The form of fertilizer applied did not affect N uptake by wheat or distribution as soil inorganic N. Of the N applied as inorganic fertilizer, 46% was taken up and 29% was found as soil organic matter. A second wheat crop the following year removed an additional 4% of the N originally in the medic and an average of 3% of the various fertilizer sources. The authors concluded that N from medic contributed 2% of the N in the first crop and 1% in the second crop per 10 kg/ha N applied. Under the same conditions fertilizer contributed 5 and 0.5% of the N in the two crops per 10 kg/ha N applied.

Use of trade names does not imply endorsement by North Carolina Agricultural Research Service, nor criticism of similar products not mentioned.

Julia B. Nelson is a Graduate Research Assistant and Larry D. King is Professor, Department of Soil Science, North Carolina State University, Raleigh, NC 27695-7619.

Experiments with ^{15}N tracer (Ladd et al., 1981; Ladd and Amato, 1986; Harris and Hesterman, 1990) indicate that a major portion of the N in green manures is not available to crops grown immediately following incorporation of the green manure. These experiments also indicate that a significant proportion of N taken up by crops is N that was mineralized during decomposition of native soil organic matter.

The objective of this study was to determine how green manure incorporated with the soil just before planting affects wheat yield, N accumulated by the wheat, and amount and distribution of inorganic soil N.

Methods

Field study

The treatments investigated were part of a larger study of cropping systems managed with current management practices (C: no-till planting and recommended rates of fertilizer and pesticides) or with reduced chemical inputs (R: chisel plowing and disking, cultivation for weed control and N from legumes) (King and Buchanan, 1993). The experiment is at the North Carolina State University Lake Wheeler Road Field Laboratory on a Cecil soil (clayey, kaolinitic, thermic Typic Kanhapludult) with 2–6% slope and moderate erosion. Soil texture ranges from sandy clay loam to loamy sand; pH averages 6.3. Treatments were arranged in a randomized complete block design with four replications with individual plots of 8 × 30 m.

The cropping systems study involves several crop rotations; to keep its size manageable, not every entry point is included in some rotations. Therefore, some crop/management combinations do not occur each year. In selecting treatments to report in this article, we could select only two that remained the same in both years of the study: wheat that received 90 kg/ha of fertilizer N and followed corn *(Zea mays)* in a 2-year rotation (C90), and wheat that received no fertilizer N and followed red clover *(Trifolium pratense)* hay in a 4-year rotation (Rgm) (Table 1). In addition, by including treatments R0 and C45 the first year (1990–91), we could observe the effect of N fertilizer rate on wheat following corn (Table 1). Similarly, by including Cgm90 and Cgm45 the second year, the combined effect of fertilizer and green manure could be observed (Table 1). At each fertilizer N rate, half was applied at planting in November and half in early March.

Table 1. Treatments in the field study.

	1990–1991		1991–1992		1992–1993		Fertilizer N applied to wheat
Treatment[1]	Winter	Summer	Winter	Summer	Winter	Summer	(kg/ha)
Rgm	—— Hay ——		Wheat	Bean	——	——	0
C90	Fallow	Corn	Wheat	Bean	——	——	90
C45	Fallow	Corn	Wheat	Bean	——	——	45
R0	Crimson clover	Corn	Wheat	Bean	——	——	0
Rgm	Crimson clover	Corn	—— Hay ——		Wheat	Bean	0
C90	Wheat	Bean	Fallow	Corn	Wheat	Bean	90
Cgm90	Fallow	Corn	—— Hay ——		Wheat	Bean	90
Cgm45	Fallow	Corn	—— Hay ——		Wheat	Bean	45

[1] C indicates current management practices; R indicates reduced chemical input management; gm indicates use of green manure. Number is N supplied by fertilizer, in kg/ha. These treatments correspond to the following treatments in King and Buchanan (1993): C45 = C2b; C90 = C2d; R0 = R2; Rgm= R4; Cgm45 = C4b; Cgm90 = C4d.

Hay preceding wheat was harvested four times in 1991 and three times in 1992, producing yields shown in Table 2. The first harvest each year consisted of red clover and ryegrass *(Lolium multiflorum)*; subsequent harvests were mixtures of red clover and johnsongrass *(Sorghum halepense)*. Hay regrowth from the last harvest until wheat planting was used as a green manure. However, in both years, regrowth was small and contained a low proportion of red clover (Table 2). We decided to simulate greater regrowth and legume content by supplementing the regrowth with a legume in the Rgm treatment (Table 2). Sufficient red clover was

Table 2. Hay yield, added green manure biomass and N, and C/N ratio.

	1991	1992			
Treatment	Rgm	Rgm		Cgm45	Cgm90
Total hay yield (kg/ha)[1]	5400	10,400		6600	6100
Biomass added (kg/ha)					
Hay regrowth[2]	1150	2360	(27%)[3]	2560 (41%)	2430
Alfalfa[4]	2160	1800		0	0
Total	3310	4160		2560	2430
N added (kg/ha)					
Hay regrowth	27	45	(38%)	57 (61%)	51
Alfalfa	80	78		0	0
Fertilizer	0	0		45	90
Total	107	123		102	141
C/N ratio					
Hay regrowth	26	24		24	25
Alfalfa	10	12		——	——

[1] The first harvest was a mixture of red clover and ryegrass. Subsequent harvests were mixtures of red clover and johnsongrass.
[2] Regrowth periods: 1991, 21 Aug–15 Oct; 1992, 7 Aug–22 Oct.
[3] Number in ( ) is percentage from red clover. Red clover was not determined in 1991.
[4] In 1991, the indicated amount of alfalfa was added to each plot. In 1992, each plot was supplemented so the amount of red clover + alfalfa was 2240 kg/ha. The average amount is shown in the table.

Table 3. Schedule of field operations.

	1991–1992 season			
	C45	**C90**	**R0**	**Rgm**
Residue management	Corn stover mowed, 9 Oct			Hay regrowth sampled & mowed, alfalfa applied 14 Oct
Tillage	see footnote 1		Disked to remove cultivation ridges 21 Oct	Chisel plowed & disked 15 Oct
Wheat	'Coker 983' planted at 70 kg/ha, 21 Oct			
Fertilizer N (kg/ha)				
5 Nov	22	45	0	0
4 Mar	23	45	0	0
Herbicide	diclofop (Hoelon) at 3.3 l/ha, 15 Nov			
Harvest	19 June			

	1992–1993 season			
	C90	**Cgm45**	**Cgm90**	**Rgm**
Residue management	Corn stover mowed, 30 Sept	Hay regrowth sampled and glyphosate (Roundup) applied (5 l/ha) 22 Oct; mowed 9 Nov		Hay regrowth sampled & mowed 23 Oct; alfalfa applied 27 Oct
Tillage	None	None	None	Chisel plowed & disked 27 Oct
Wheat[2]	'Southern States 555' planted at 200 kg/ha			
	9 Nov	9 Nov	9 Nov	27 Oct
Fertilizer N (kg/ha)				
11 Nov	45	23	45	0
9 Mar	45	22	45	0
Herbicide	None			
Harvest	18 June			

[1] Wheat was no-till planted, but because of a poor stand, treatments C45 and C90 were chisel plowed and disked, and wheat was replanted 18 Nov.
[2] Because of dry soil conditions, no-till planting was delayed until after rain.

not available at the site, so we used alfalfa from an adjacent field. The alfalfa was harvested with a flail chopper and appropriate quantities were weighed out and applied to the plots. Field operations are shown in Table 3.

We sampled hay regrowth before plowing by collecting all above-ground biomass in four 0.25 m^2 quadrats in each plot. Wheat was sampled four times during the growing season using the same technique. Volunteer crimson clover was present in some wheat plots. We omitted it from the wheat biomass samples except for the harvest sample in June 1992, when the amount of crimson clover was large. The clover and wheat were separated at this sampling date. Biomass samples were dried at 65°C, ground to pass a 1-mm sieve, and analyzed for total C and N by combustion in a pure O_2 environment using a Perkin-Elmer 2400 CHN elemental analyzer (Perkin-Elmer, 1987).

Soil sampling to 30 or 90 cm was scheduled at two-week intervals, but some sampling dates were omitted if there had been little rain since the last sampling date. Also, there was probably little nitrate movement. We also did not sample if the soil was too dry or too wet to sample to 30 cm. Samples were air dried, ground to pass a 2-mm screen, and stored at room temperature in small cardboard boxes. They were extracted with 2M KCl, and NO_3^-–N and NH_4^+–N were determined colorimetrically on a Lachat auto analyzer (Lachat Instruments, 1990a,b). We converted concentrations to kg/ha per 20-cm layer using bulk density measurements, correcting for gravel content (Crozier, 1992).

We analyzed all data using analysis of variance (SAS Institute, 1985). Means were compared using the least significant difference at a 5% probability level ($LSD_{.05}$).

Laboratory study

Since the green manures in the field study would be decomposing under winter conditions, we conducted a laboratory study to determine the rate of N mineralization from green manure at the average winter soil temperature for the experimental site. A bulk sample of sandy loam soil was collected from the experimental site and sieved at field moisture content to pass a 2-mm screen. Clover leaves were collected from the site, placed in plastic bags, and refrigerated until used. No flowers were present when the clover was collected, and we discovered after the experiment was well under way that white clover *(Trifolium repens)* rather

than red clover had been collected. Clover characteristics and application rates (treatments) are shown in Table 4.

Clover and 40 g of field-moist (110 g/kg) soil were placed in 125-ml Erlenmeyer flasks. We left the leaves whole unless they had to be cut to achieve the correct weight. The flasks were covered with plastic film containing small holes to minimize evaporation while allowing gas exchange. The samples were placed in a refrigerator in a randomized complete block design with three replications. Temperature was maintained at 10°C.

We prepared an appropriate number of flasks so that three replications of each treatment could be destructively sampled at one-week intervals until week 5, and then at two-week intervals thereafter. At week 9, the remaining flasks were brought back to their original weight with distilled water. On average, 0.9 g (about 25% of the original water) had been lost. Clover and soil samples were analyzed with the same procedures used in the field study.

For each sampling date, we used analysis of variance to determine if treatments were significantly different (SAS Institute, 1985). Least significant difference at the 5% level of probability was used to separate significantly different treatments ($LSD_{.05}$).

Table 4. Characteristics and application rates of white clover leaves and percent recovery of the applied N as inorganic N after 15 weeks of incubation at 10°C.

Treatment	N (g/kg)	C/N	Application Rate: Dry Weight[1] (Mg/ha)	Application Rate: N (mg/kg soil)	N Recovered (% of applied)
0	—	—	0	0	—
16	45.9	9.7	0.7	16	81
32	"	"	1.4	32	73
65	"	"	2.8	65	72
					$LSD_{.05}$ 11

[1] Based on bulk density of 1.4 Mg/m^3.

Results

Wheat biomass and N content

During the 1991–92 season, wheat biomass was greater with the green manure N source (Rgm) than with fertilizer N (C45>C90) through the April sampling date (Fig. 1). At subsequent dates, biomass was in the order C90>Rgm = C45> R0. Nitrogen content of the wheat biomass was higher with green manure than with fertilizer N at the December sampling date (Fig. 1). Thereafter, biomass N increased in the fertilizer treatments, and with both N treatments the increase in biomass N between December 20 and March 29 was similar to the quantities of N applied to these treatments on March 4. At harvest, N sources and rates had no significant effect on biomass N.

During the 1992–93 season, wheat biomass was not affected significantly by treatments until the final sampling date (Fig. 1). Green manure supplemented with 90 kg N/ha (Cgm90) was superior to green manure alone (Rgm) or 90 kg N/ha alone (C90).

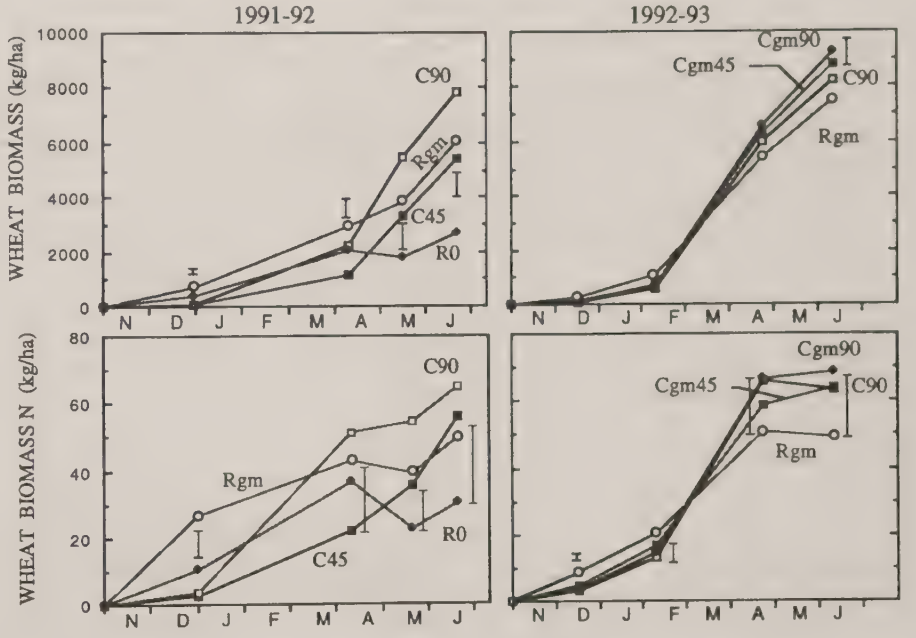


Fig. 1. Above-ground wheat biomass and N in the biomass. Error bars are $LSD_{.05}$. Absence of bar indicates no significant differences.

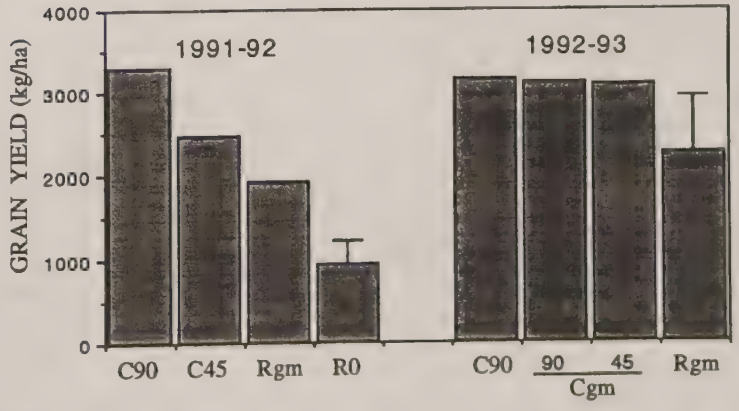


Fig. 2. Wheat grain yield. Error bars are $LSD_{.05}$.

Green manure alone (Rgm) resulted in wheat biomass N content greater than or equal to those with the other treatments until the last sampling date. At that time, supplementing green manure with 90 kg N/ha (Cgm90) resulted in higher N content than did green manure alone (Rgm). Differences in N content among treatments receiving fertilizer N were not significantly different at this time.

In contrast to above-ground biomass and biomass N content, treatment differences among grain yields were significant in 1992 (Fig. 2). In 1993, differences in grain yield among N-fertilized treatments were not significant, but these treatments were greater than Rgm. The contrast between lack of treatment effect on biomass yield (and biomass N content) and the significant effect of treatments on grain yield in 1992 may have resulted from differences in N supply during head differentiation. Since an adequate N supply during differentiation increases head size (and thus yield potential), the N applied to C45 and C90 in March may have increased head size more than did the small quantity of N supplied by mineralization of the green manure N.

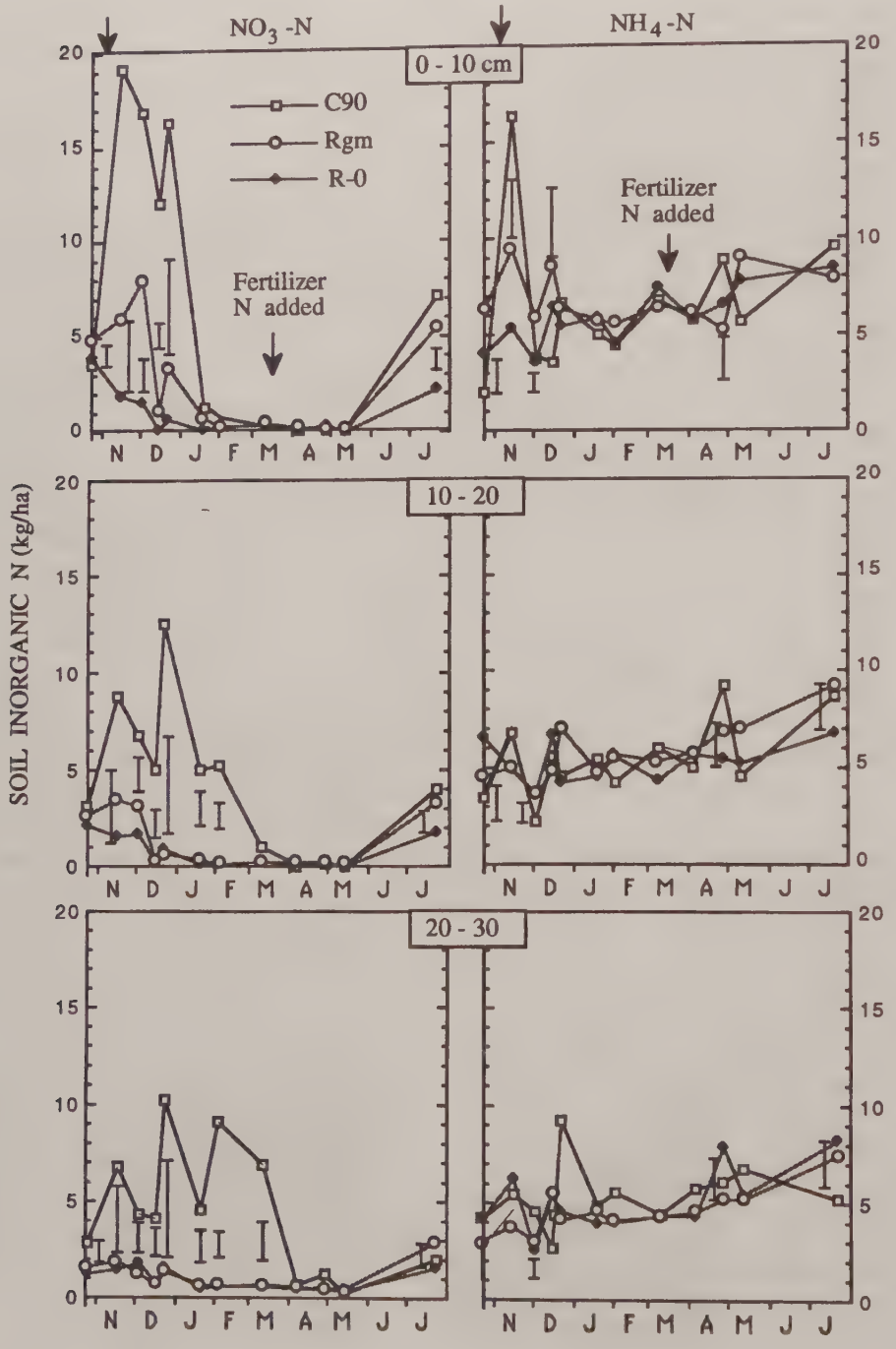


Fig. 3. Effect of N fertilizer (C90), green manure (Rgm) and no addition (R0) on soil inorganic N at three soil depths, 1991-1992. Significant differences noted as in Fig. 1.

Soil inorganic N

The effects of fertilizer N and legume N on soil NO_3^-–N and NH_4^+–N concentrations in 1991–1992 are shown in Fig. 3. (C45 was omitted to improve the clarity of the figures.) In the 0- to 10-cm layer, fertilizer N (C90) increased NO_3^-–N concentrations above those with no N inputs (R0) or with N from green manure (Rgm). Only in November and early December was NO_3^-–N higher with Rgm than with R0. In all treatments, concentrations dropped to near zero by January and remained low until after wheat harvest in June. At greater depths, the trend was the same except that R0 and Rgm did not differ significantly. As depth increased, the decline in NO_3^-–N concentration to very low levels was delayed. This delay suggests a downward movement of NO_3^-–N in January and February, when growth was slow, with later extraction of NO_3^-–N, as roots grew deeper into the profile. In the two lower depths, the higher NO_3^-–N content in C90 compared with R0 suggests greater downward movement of fertilizer N than of green manure N.

A high NO_3^-–N concentration occurred in C90 on November 13, probably caused by fertilization on November 5. In contrast, no such peak occurred at the March 29 sampling date, despite the application of fertilizer N on March 4. Rapid uptake of N by wheat during this 25-day period may have prevented the accumulation of NO_3^-–N.

In November and December, NH_4^+–N concentration in the 0 to 10-cm layer was significantly affected by treatment. At later sampling dates, differences were seldom significant at the other depths. As with NO_3^-–N, a fertilizer-induced peak was noted in the fall but not in the spring. NH_4^+–N concentrations were nearly constant for all treatments after January.

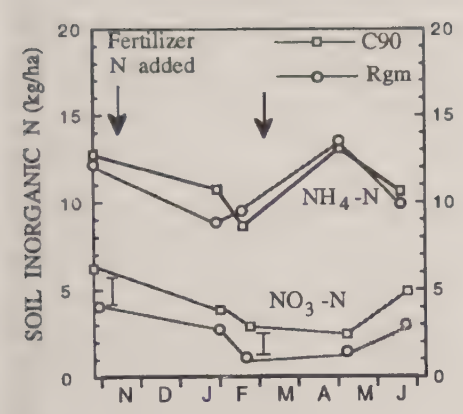


Fig. 4. Effect of fertilizer N (C90) or green manure (Rgm), on soil inorganic N in the 0- to 30-cm soil layer, 1992–1993. Significant differences noted as in Fig. 1.

Because of wet conditions, we could not sample the soil in November and December 1992. We combined the data over depths, and present them for the 0 to 30-cm layer (Fig. 4). (Cgm45 and Cgm90 were omitted to improve clarity of the figures.) By February, the soil NO_3^-–N concentrations were low, following a trend similar to the previous year's. Concentrations were consistently higher with C90, but only in November and February were the differences significant. NH_4^+–N concentrations were higher than those of NO_3^-–N, but treatment differences were not significant.

Distribution of NO_3^-–N as a function of depth and time is shown in Fig. 5. In October 1991, before fall fertilizer application, NO_3^-–N concentration declined with depth. By March, the NO_3^-–N concentration in the surface layer had declined and the downward movement of NO_3^-–N can be observed by the increased concentrations at lower depths in the C90 treatments. By July, surface NO_3^-–N concentration had increased and NO_3^-–N in the lower levels had declined. In the lower part of the profile, variation with time was not significant in the Rgm treatment, indicating a lack of excess NO_3^-–N available for leaching.

In 1992–93, NO_3^-–N profiles were similar to those in 1991–92 but differences were not as pronounced (Fig. 5). At the lower depths, NO_3^-–N in C90 was significantly higher than in Rgm.

Laboratory study

Nitrate-N accumulated very slowly as the clover decomposed (Fig. 6). Only after 10 weeks did clover increase the NO_3^-–N concentration above the control. In contrast, NH_4^+–N accumulated rapidly for about 3 weeks, and differences among treatments were significant. Concentrations remained nearly constant after 3 weeks but declined toward the end of the study as nitrification rate increased. Inorganic N recovered from clover was determined by combining NO_3^-–N and NH_4^+–N, deducting the control, and expressing the result as percent of applied N. Application rate had no significant effect on recovery, and about 75% of the applied N could be accounted for at 15 weeks (Fig. 6).

N budgets

Soil inorganic N data for 1991–92 shown in Fig. 3 were combined with biomass N

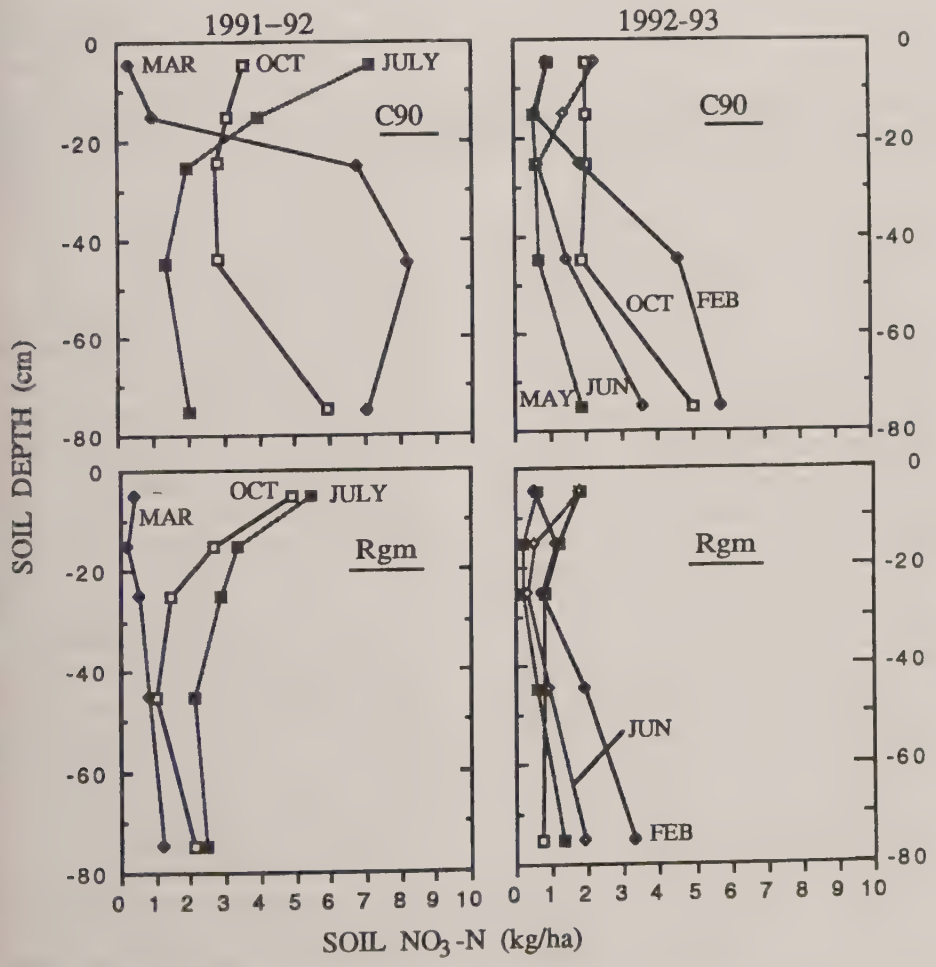


Fig. 5. Effect of fertilizer N (C90) and green manure (Rgm) on distribution of soil inorganic N at several sampling dates each season. $LSD_{.05}$ 1991–92, 2.2 kg/ha; 1992–93, 1.4 kg/ha.

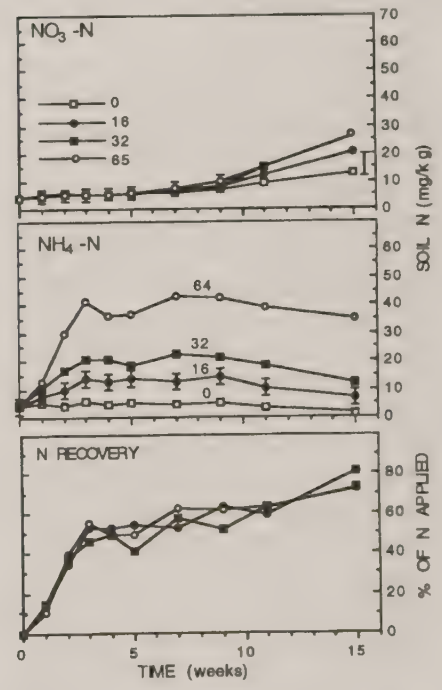


Fig. 6. Effect of fresh clover additions (supplying 16, 32, or 65 mg N/kg soil) on accumulation of inorganic N and recovery of applied N. Significant differences noted as in Fig. 1. Treatments listed in Table 4.

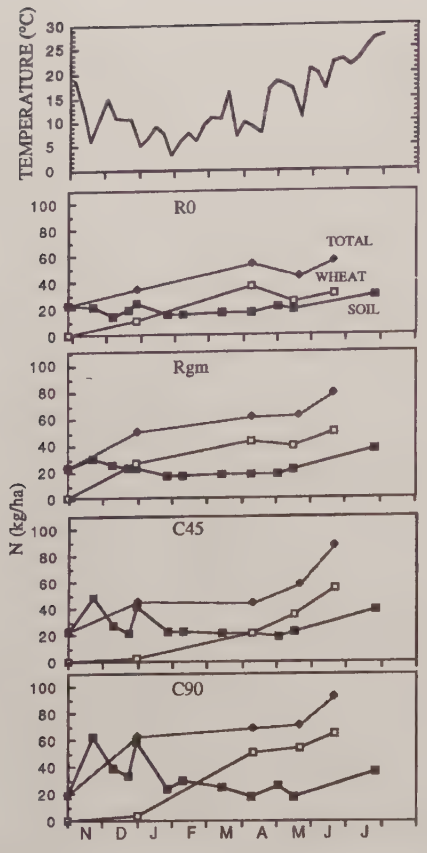


Fig. 7. Nitrogen in above-ground wheat biomass, soil inorganic N in top 30 cm, sum of wheat and soil N, and weekly average air temperature, 1991–92.

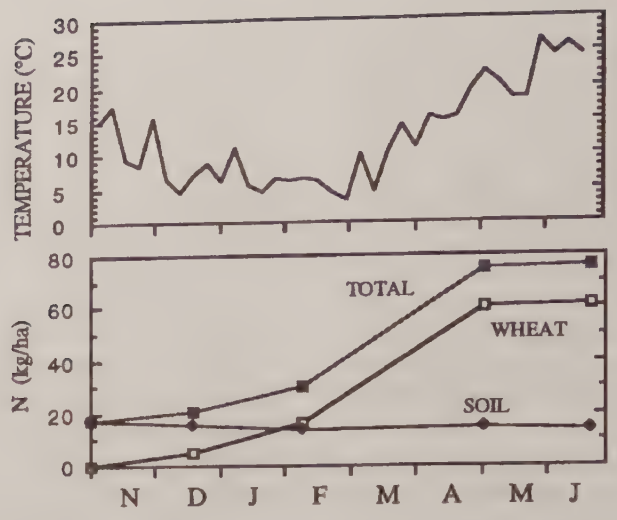


Fig. 8. Nitrogen in above-ground wheat biomass, soil inorganic N in top 30 cm, sum of wheat and soil N, and weekly average air temperature, 1992–93 (data averaged across treatments).

presented in Fig. 1 to show the relationship between soil and biomass N pools during the growing season (Fig. 7). The nearly constant level of soil N while biomass N increased in the spring, even considering fertilization, suggests that although the soil inorganic N pool was nearly constant, increasing soil temperature increased N mineralization rate so that mineralization and plant uptake rates were similar, or that N was being recovered from below the sampling depth of 30 cm.

A similar N budget graph was generated for 1992–93 (Fig. 8). However, because differences among treatments generally were not significant, we show only the average of all treatments. As in 1991–92, soil inorganic N did not vary appreciably as wheat N increased.

In the laboratory study, net inorganic N at the end of 15 weeks in the clover treatments (N in clover treatment – N in control) ranged from 72 to 81% of the clover N applied. In the field study, soil N + biomass N for R0 was subtracted from soil N + biomass N for Rgm (Fig. 7) to estimate N released from green manure (21% of applied N). The lower recovery in the field study may in part be caused by the higher C:N ratio of the johnsongrass-red clover-alfalfa mixture (weighted average of 16 compared with 10 for the clover used in the laboratory study) and by movement of NO_3^-–N below the 30-cm depth sampled.

Management options

Data from both years indicate that in the fall, decomposing green manure supplies sufficient N for wheat growth, but in the spring, N from the green manure is inadequate. In 1992–93, combining green manure N with fertilizer N (Cgm45 and Cgm90) did not increase grain yields above those with fertilizer N only (C90). Thus, green manure (johnsongrass and red clover) did not affect yield significantly when combined with fertilizer additions, but permitted reduced fertilization without sacrificing wheat yield.

Some of the N applied in the fall apparently is lost by leaching, especially in the fertilizer treatments. A system using green manure in the fall and fertilizer N in the spring may avoid the problems of leaching and decreased yield.

Conclusions

Generally, above-ground wheat biomass and N in that biomass were greater with green manure than with fertilizer N in the fall and winter. Thereafter, green manure N resulted in equal or lower biomass and N than did fertilizer N. In 1992, N in the above-ground wheat biomass was equivalent to 56% of the 45 kg/ha of applied fertilizer N and 37% of the 90 kg/ha, but only 18% of the 107 kg N/ha contained in the green manure.

Wheat yield was lower with green manure (Rgm: red clover + alfalfa + johnsongrass) containing 107 to 123 kg N/ha than with the recommended rate of 90 kg/ha fertilizer N (C90). Green manure (red clover + johnsongrass) containing 57 kg N/ha supplemented with 45 kg/ha fertilizer N (Cgm45) produced yields similar to the fertilizer N at 90 kg/ha.

In 1991–92, soil NO_3^-–N concentrations were high in the fall, then declined markedly as wheat growth increased in the spring. In contrast, although NH_4^+–N concentrations were temporarily elevated in the fall, they remained nearly constant from December through June, with treatment differences seldom significant. In both years, NH_4^+–N was higher than NO_3^-–N from January through July. During the growing season, soil inorganic N concentrations remained nearly constant while N in wheat increased, suggesting synchrony between mineralization and N uptake. The higher NO_3^-–N concentration in the 20 to 80-cm soil zone with fertilizer N compared with green manure suggests a greater leaching potential from fertilizer N than from the green manure.

The management option suggested by these results is to use green manure as an N source for wheat with supplementation with fertilizer N in the spring. This combination should produce acceptable yields and decrease the potential for leaching of NO_3^-–N.

Acknowledgment. We appreciate the technical assistance of Mark Barnes, Guillermo Ramirez, and Deborah Steely.

References

1. Badaruddin, M., and D.W. Meyer. 1990. Green-manure legume effects on soil nitrogen, grain yield and nitrogen nutrition of wheat. Crop Sci. 30:819–835.
2. Crozier, C.R. 1992. Tracing nitrogen movement in North Carolina Piedmont corn production systems using N pool size analysis and ^{15}N tracing. Ph.D. dissertation. Dept. of Soil Science, North Carolina State Univ., Raleigh.
3. Doyle, A.D., K.J. Moore, and D.F. Herridge. 1988. The narrow leafed lupine (*Lupinus angustifolius*) as a nitrogen fixing rotation crop for cereals production, III. Residual effects of lupines on subsequent cereal crops. Australian J. Agric. Res. 39:1029–1037.
4. Harris, G.H., and O.B. Hesterman. 1990. Quantifying the nitrogen contribution from alfalfa to soil and two succeeding crops using nitrogen-15. Agronomy J. 82:129–134.
5. King, L.D., and M. Buchanan. 1993. Reduced chemical input cropping systems in the southeastern United States. I. Effect of rotations, green manure crops and nitrogen fertilizer on crop yields. Amer. J. Alternative Agric. 8:58–77.
6. Lachat Instruments. 1990a. QuikChem method NO. 10-107-04-1-A. Nitrate + Nitrite. Lachat Instruments, Milwaukee, Wisconsin.
7. Lachat Instruments. 1990b. QuikChem method NO. 12-107-06-2-B. Ammonia in soils. Lachat Instruments, Milwaukee, Wisconsin.
8. Ladd, J.N., and M. Amato. 1986. The fate of nitrogen from legume and fertilizer sources in soils successively cropped with wheat under field conditions. Soil Biology and Biochemistry 18:417–425.
9. Ladd, J.N., J.M. Oades, and M. Amato. 1981. Distribution and recovery of nitrogen from legume residues decomposing in soils sown to wheat in the field. Soil Biology and Biochemistry 13:251–256.
10. Perkin-Elmer. 1987. Instruction manual 0993-7147. Norwal, Connecticut.
11. Reeves, T. G., A. Ellington, and H.D. Brooke. 1984. Effect of lupine-wheat rotations on soil fertility, crop disease, and crop yields. Australian J. Experimental Animal Husbandry 24:595–600.
12. SAS Institute. 1985. SAS User's Guide: Statistics. Cary, North Carolina.
13. Strong, W.M., J. Harbison, R.G.H. Nielsen, B.D. Hall, and E.K. Best. 1986. Nitrogen availability on a Darling Downs soil following cereal, oilseed and grain legume crops. 2. Effects of residual soil nitrogen and fertilizer nitrogen on subsequent wheat crops. Australian J. Experimental Agric. 26:353–359.
14. Zentner, R.P., E.D. Spratt, H. Reisdorf, and C.A. Campbell. 1987. Effect of crop rotations and N & P fertilizer on yields of spring wheat grown on a Black Chernozemic Clay. Canadian J. Plant Sci. 67:965–982.

INSTITUTE NEWS

Henry A. Wallace Honored with Festivities at Birthplace

Henry A. Wallace was recognized last October in Iowa with a dinner in honor of the extended family of Henry A. and Ilo Browne Wallace, the dedication of his birthplace, and an all-day country life folk festival. The dinner program, which was hosted by Pioneer Hi-Bred International and Iowa State University, gave tribute to the "Wallace family legacy," which continues today with his daughter, Wallace Institute Honorary President Jean Wallace Douglas, and his sons, Robert B. Wallace, and H.B. Wallace.

The tribute particularly praised Henry A. Wallace, who represented "'good farming, clear thinking, and right living,' and planted the seeds that grew such Iowa State programs as agronomy and applied statistics into international powers."

Wallace's birthplace in Greenfield, Iowa, was dedicated as the Henry A. Wallace Country Life Center, and celebrated with a country life festival which featured theater, puppetry, music, poetry, and the works of Iowa artists.

The birthplace dedication address was given by former Iowa Senator John C. Culver who said that Wallace "would have enjoyed this scene. Much of what he held dear is represented here today. The joy and satisfaction of rural life. The honor and duty of family. The importance of cooperative effort, the beauty of nature, the value of conservation. These were essential elements of Henry Wallace, the private man and the public figure....We know he believed the land and the people who tend it are the foundation upon which all civilization rests. Like Thomas Jefferson, he believed the farmer was performing God's work."

Culver described Wallace as a man who "lived in cities large and small; travelled the world and knew its leaders; edited an influential farm journal and a famous magazine; blazed new trails in economics, statistics, and plant genetics; founded a great business, served in the Cabinet, became vice president of the United States and ran for the presidency—but his guiding principle was grounded here, in the soil of Adair County."

Wallace's birthplace, according to Culver, is "an unusually fitting memorial to his life and work. Here on this farm, and in this modest farmhouse, we can see expressed the values that informed his life: The great drama of sowing and reaping; the satisfaction of hard work; our responsibility to the land and to our fellow man; the dignity of common people, the beauty of nature, the glory of God.

"And, of course, family. The great importance of family to the Wallaces, and the peerless contribution the Wallace family made to American life and agriculture are symbolized by this site."

Wallace's heart and soul never left the land of his birth, Culver said. "His was a lifetime of unprecedented service to the cause of agriculture and scientific work that revolutionized world food production to the benefit of all mankind. The efforts made to preserve land were among his proudest accomplishments."

Culver ended his address by quoting Wallace himself, who said, "The improved quality and increased abundance of life is a progressive matter and has to do not only with human life but with all plants and animals as well...the highest joy of life is complete dedication to something outside yourself."

continued on page 192

BOOK REVIEWS

Fundamentals of Soil Ecology. By David Coleman and D.A. Crossley, Jr. 1996. Academic Press, Inc., 525 B St., Suite 1900, San Diego, CA 92101; 800-321-5068. $35.00, hardcover. xv+205 pp.

Anyone who has taught a soil ecology class and searched fruitlessly for one good text is likely to be pleased with *Fundamentals of Soil Ecology*, by David Coleman and Dac Crossley, Jr., of the University of Georgia. On first glance through this compact volume, I recognized many of the tables and figures that I previously compiled in my own soil ecology reader. On closer examination, I found the book to be well written and edited, offering an excellent synthesis of current knowledge. I appreciated the summaries that close each chapter with a thoughtful and succinct review.

Although written from an academic perspective, the authors make clear from the start that in their opinion, life of the soil is critical to the survival of human civilizations. They quote Daniel Hillel's comment that "the plow has caused more destruction to civilization than the sword," and suggest that the adage "beating swords into plowshares" needs rethinking. The scope of their material is the territory where soil science intertwines with ecology. To the standard definition of soil as a mechanical and chemical entity, these authors add living organisms as a fundamental part of soil.

The book is organized into seven chapters, the first giving an overview of soil physical characteristics, with an early emphasis on the importance of water in mediating soil life. Next the authors focus on primary productivity, "the principal biochemical motive force for all subsequent activities of heterotrophs in soils." Chapters 3 and 4 introduce the heterotrophs, first microbes and then animals, covering their ecological significance and some ways in which they can be studied. While soil microorganisms are "the eye of the needle" through which most decomposing organic materials pass, the fauna are "mechanical blenders" that interact with soils and substrates in ways that strongly influence microbial processes.

Chapter 5 deals with decomposition and nutrient cycling, which the authors present as functional properties that combine the actions of all soil aspects. They suggest that while details such as measurements of microbial biomass or other soil components are important, soil ecologists must strive to consider these details in a holistic perspective. Chapter 6 examines food webs, with the authors introducing the intriguing idea of focusing soil ecology studies on "hot spots." These are the areas, occupying less than 10% of soil volume, in which 90% of all soil biological activity may take place; they include the area around roots (the rhizosphere), earthworm tunnels (drilosphere), and any concentrations of readily decomposable organic matter. In the final chapter, the authors heed their own holism recommendation and step back to offer the big picture of soil ecology, which includes global carbon dynamics, biodiversity, coevolution of species, and finally, evolution of the soil environment in relation to the Gaia hypothesis.

The authors treat soil ecology as a frontier science with much information still to be uncovered: "The tools and analytical skills are at hand: it is now necessary to proceed with as much care in the assessment and measurement of belowground processes as has heretofore been given to aboveground processes." The authors have met the challenge of producing a good soil ecology text. Now it is up to soil ecologists and others to meet the challenges presented by this text.

Matthew Werner, Center for Agroecology and Sustainable Food Systems, University of California, 1156 High Street, Santa Cruz, CA 95064.

Regenerating Agriculture: Policies and Practice for Sustainability and Self-Reliance. By Jules N. Pretty. 1995. Joseph Henry Press, 2101 Constitution Ave., Washington, DC 20418. $44.95, hardcover; $24.95, paper. ix+320 pp.

As director of the Sustainable Agriculture Program of the International Institute for Environment and Development in London, Jules Pretty has access to in-depth information on a range of current development projects. He has woven this experience into a timely and optimistic look at the potential for future food production if technologies are used wisely.

Following his overview or vision of sustainable agriculture, Pretty discusses the modernization process (Chapter 2), with examples from both the industrialized countries and the Third World, along with the environmental and social costs of these advances (Chapter 3). Chapter 4 describes technologies and processes that can be used to conserve soil and water and manage pests and soil nutrition, and it discusses the importance of their adoption by farmers. Pretty provides examples of how both local groups and external partnerships are essential to the development process (Chapters 5 and 6). He concludes with three chapters on the importance of agricultural policy and how it can influence the transition to a sustainable agriculture.

The book is heavily referenced. The author includes many side bars, tables, figures, and examples set aside in boxes that bring his development experience to support the general thesis of change toward a more sustainable future. Without minimizing the magnitude of the challenges in sustaining food production, Pretty provides a refreshing look at what is going on in the developing world and how we can build on positive examples. I recommend this book highly for upper division undergraduate students and anyone interested in unique examples of current progress in Third World countries.

Regenerative agriculture is most successful when the focus on resource-conserving technologies is combined with thoughtful coordination of projects at the community level and with support of government or other organizations from outside. The author provides an expected list of the failures of the Green Revolution, including the unequal distribution of its benefits, and suggests that any strategy that depends on a single approach is likely to lead to stagnation. This would be borne out by the record of the World Bank, the Consultative Group on International Agricultural Research, and the U.S. Agency for International Development, whose traditional strategies seek simplistic solutions to the global food dilemma. *Regenerating Agriculture* goes beyond the usual chronicle of problems and alternative technology solutions by challenging our predominant learning paradigms, namely the

positivism and domination of the hard sciences. The author urges us to accept that values should be an explicit component of decision making.

As an example of both the holism needed in thinking about future systems and of our failure to consider indigenous knowledge and success seriously, Pretty describes rice production with a yield of 6 t/ha in the terrace systems of Bontoc in the Republic of Philippines: "Weeds and wild plants [are] collected to keep the terraces clear for fear of rat infestation; soil fertility is maintained with the use of *Azolla*, pig manure composts, and the import of mountain soils; and irrigation water is managed communally. Success is a function of both the resource conserving technologies and the organized community action to make best use of them." Such specific examples throughout the book bring credibility to the arguments for a more sustainable development strategy.

The Green Revolution in its several forms has made a substantial contribution to world food supply and has bought time for us to seek solutions to human population growth and establish a wider range of creative strategies for food production. Pretty gives us examples of both the successes and the challenges, in human economic terms, of this dominant approach of the past five decades. He outlines the environmental and social costs of a simple, high technology strategy and provides examples of alternatives that have worked. The national effort to reduce pesticide use in Indonesian rice production systems while maintaining yields and increasing profits provides a valuable lesson to those who have worked hard to transplant technologies from one region to another and have been frustrated by lack of long-term success. International development planners and agencies are beginning to learn from these successful examples.

In Chapter 4 the author gives a well-documented review of resource-conserving technologies, including biological control of pests, integrated nutrient management, and innovative systems such as agroforestry. He describes the soil conservation techniques used in both temperate and tropical regions and the potential successes of some field design strategies. Although the chapter provides a good introduction to the topic, much of this has been covered before. What makes the book special are the five following chapters that link local groups, community action, policy, and outside sources of support.

The value of local groups and institutions is illustrated with several cases from Third World settings. Their goals include organization and control of water use, watershed-level group decisions on how to manage soil erosion, and increasing access to credit for production inputs. The process leads to longer-term change and improvement if local users are involved in participatory planning and management of the initiative. Further stability can be achieved by local groups banding together to effect change at the watershed, district, or national level. The successful ACCORD project in Burkina Faso that coordinates the efforts of several donor agencies and nonprofit groups illustrates the power of coordinated planning and efficient use of limited funding.

How our understanding of local needs and priorities for development become distorted is explored in Chapter 6. Distortion of reality can be the result of highly structured questionnaires designed for predetermined results ("Self Deception and Questionnaire Surveys") and quick field visits by development professionals ("Self Deception and Rural Development Tourism"). Pretty describes the spatial and temporal biases that are inherent in many evaluation visits, and how they skew decisions toward a small segment of the real challenges facing small farmers trying to produce food for their families and for the market. The emerging appreciation of how people can search for their own solutions through participatory research and extension projects and how development agencies can provide support for this approach gives hope for the future. A specific example from Nepal illustrates how a farmer who received lentil seed tried three different locations and times of year before he learned where the crop could be grown successfully, and how this same information was subsequently used by researchers to design field trials with relevant treatments. The author maintains that such participatory approaches will be fostered by "learning organizations" that promote experimentation and diversity of programs, group activities, and careful monitoring and self-evaluation of projects.

A well-referenced series of tables in Chapter 7 summarizes the documented impacts of various resource-conserving technologies, including alternative soil amendments to enhance fertility, measures to prevent erosion, integrated pest management, and appropriate irrigation scheduling to save water and reduce production costs. A section follows that presents case studies from 20 different communities, with a summary of the process and the effects on productivity or economic return. In this age of accountability, there is no substitute for providing specific information on impacts on the number of farms, area where change has occurred, increased economic return, reduced economic risk, and environmental change.

The overriding importance of agricultural development policy is described in the final two chapters, with a description of how current policies often serve as disincentives to change. Switching from high-input to resource-conserving practices incurs transition costs that often are related to policy. Subsidies for pesticides and irrigation water are examples of government interventions that influence decisions at the farm level, while heavy taxes on agriculture and exports have distorted the marketplace in favor of other industries. Finally, most development policies related to agriculture have ignored the long-term social and environmental costs of conventional approaches and the potential contribution of alternative technologies and systems to resource-efficient food systems. A series of 25 specific policies that have been used to promote sustainable agriculture are described. Although not a prescriptive approach, this list offers creative options that can be studied for the design of a specific strategy that is appropriate for the resources and societal goals in a given place and time.

Regenerating Agriculture is a valuable introduction to comprehensive improvement of the global food system. The author describes a range of resource-conserving practices and advocates that we focus carefully on the need for changes in agricultural policy. The book contains many specific examples of success. It is easily read and would be readily accessible to a general audience. It also would be appropriate for advanced undergraduates or for a graduate course in agricultural development, and for students in production sciences, nutrition, economics, or political science. When choosing a text for any course in sustainable agriculture, instructors would be well advised to consider this one.

Charles Francis, Center for Sustainable Agricultural Systems, University of Nebraska, Lincoln, NE 68583-0949.

Applications for 1997 Ward Sinclair Internship Due March 15

To honor the late Ward Sinclair — an organic farmer, a writer, and a member of the Wallace Institute's Board of Directors — the Wallace Institute awards one internship each year to a person desiring the "hands-on" experience of working on a farm that produces and direct-markets food, combined with a policy exercise dealing with the direct marketing of food. Interns spend approximately half their time working at the Flickerville Mountain Farm and Ground Hog Ranch in Dott, Pennsylvania, the farm established and managed by the late Ward Sinclair, and Cass Peterson, who supervises this half of the internship. In 1997, the other half of the internship will be spent working with the Pennsylvania Association for Sustainable Agriculture on marketing issues.

Applications for the 1997 Ward Sinclair Memorial Internship Program are due on March 15. For more information or a brochure about the internship, contact the Wallace Institute, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770; (301) 441-8777.

Wallace Institute Launches New Policy Project; Clancy Named Director

The Wallace Institute has launched a new project, "Designing a Policy Framework for Food, Agricultural and Rural Sustainability." The five-year project is being funded by the W. K. Kellogg Foundation of Battle Creek, Michigan, which has contributed $2 million to be dedicated solely to the project. The director of the effort is Kate Clancy, former Professor of Human Nutrition at Syracuse University, New York.

Building on work already begun by regional sustainable agriculture working groups, the Integrated Farming Systems Network, the Campaign for Sustainable Agriculture, and other efforts, the project will seek to develop a shared vision of sustainable agriculture and supportive food and agriculture policies at the local, state, and national level. Working with sustainable agriculture leaders across the country, Clancy will organize and lead a systematic process to create the foundation for longer-term and proactive policy development and decision-making for a sustainable food and agricultural system. The Wallace Institute staff and others will then analyze these interacting policy proposals to identify their tradeoffs, costs, and benefits, and make the results widely available to Congress, government agencies, and the public.

Clancy had been at Syracuse University from 1982 to 1996. In 1985, she was a Visiting Fellow at the National Center for Food and Agriculture Policy in Washington, D.C. For a semester in 1995, she was a Visiting Professor at the Center for Integrated Agricultural Systems at the University of Wisconsin at Madison. She served on the Wallace Institute's Board of Directors from 1988 to 1994, and has also served as President of the Agriculture, Food and Human Values Society.

Wallace Institute Board Elects Four New Members

The Wallace Institute's Board of Directors, at its mid-year meeting in September, 1996, in Gainesville, Florida, elected four new members who will start their terms in March. The board meeting was preceded by a reception hosted by the Institute of Food and Agricultural Sciences at the University of Florida.

The four new members elected to the Wallace Institute Board are: Desmond A. Jolly, Agricultural and Consumer Economist, Department of Agricultural Economics, University of California, Davis; Extension Economist, University of California; and Director, Small Farm Program, University of California. Deborah A. Neher, Assistant Professor, Department of Biology, University of Toledo; former Visiting Assistant Professor and Research Associate, Department of Plant Pathology, North Carolina State University; and former Research Assistant, Department of Plant Pathology, University of California, Davis. Robert I. Papendick, Soil Scientist, Department of Crop and Soil Sciences, Washington State University; former Research Leader and Supervisory Soil Scientist, Land Management and Water Conservation Research Unit, USDA-ARS, Pullman, Washington; and former Research Leader, Subarctic Agricultural Research Unit, USDA-ARS, Fairbanks, Alaska. Frederick V. Payton, Assistant Professor, Institute of Community and Area Development, University of Georgia; Director, Southwest Georgia Alternative Agriculture Project; and former Senior Scientist and Interim Director, Central America and Caribbean Region, International Potato Center.

Dr. Vidaver Named to New USDA Advisory Board

Dr. Anne Vidaver, President of the Wallace Institute Board of Directors and Chair, Department of Plant Pathology at the University of Nebraska-Lincoln, has been named to the newly created USDA National Agricultural Research, Extension, Education, and Economics Advisory Board, authorized by the 1996 farm bill. The board will advise the Secretary of Agriculture and land-grant colleges and universities on agricultural research, extension, education, and economic policy and priorities.

Thompson Farm Publishes Annual Research Report

"Alternatives in Agriculture," the 1996 annual research report of Thompson On-Farm Research in Boone, Iowa, is now available. The report updates all previous reports with summaries of the research done by Dick and Sharon Thompson, and is published to be "helpful to both farmers and the research community." Research is categorized in nine chapters: Inspiration, Documentation, Education; Fertility; Cover Crops; Alternative Weed Management; Crops; Water Quality-Soil Health; Economics; Livestock; and Farming for Better Communities. The publication of the report and the 1996 research work at the Thompson Farm is made possible by the financial support of Mrs. Jean Wallace Douglas through the Wallace Institute. Copies of the report are $10 each from Thompson On-Farm Research, 2035 190th Street, Boone, IA 50036-7423; (515) 432-1560.

Guide for Authors

The American Journal of Alternative Agriculture (AJAA) publishes original research on biological, physical, or social science aspects of alternative agriculture. We particularly welcome multi-disciplinary studies, but papers from a specific discipline also are invited. However, since AJAA readership is much broader than for a single-discipline journal, highly specialized terminology should be explained or avoided. The significance of a statement, or the reasoning behind a conclusion, may have to be spelled out more than in a more specialized journal. See Vol. 5, No. 1, pp 2 & 3, for an explanation of the various categories of articles.

Units

Research papers should use the International (SI, or metric) system throughout. Occasional use of common unit equivalents in parentheses is permitted.

Title page

The title page should give the following information (all flush left): 1) title of the paper; 2) names of authors; 3) affiliation and office address of authors, and 4) disclaimers and publication number, if any. See examples in this issue of AJAA.

Abstract

The abstract should be 200 to 400 words suitable for readers from a broad range of disciplines. It should avoid highly-specialized terminology that might be appropriate for a single-discipline journal. Take particular care that the significance of the work is made clear, even to readers from a different field.

Key words

Provide subject matter key words suitable for use in scientific indexing.

Reference list

When citing material that has been covered in more than one format, such as the typescript of a conference presentation and a journal article, preference should be given to the version that is most readily available, and that is likely to remain so. Generally this means standard publication channels, such as books, journals, and regular government report series. Unpublished or informally-published material should be cited only when no alternative form exists.

References should be listed in alphabetical order by author's name, and by year for a particular author (with letters after the year if needed). If a sole author is also the lead author of papers with multiple authors, use the following order: single author (by year); two authors (alphabetically by second author's name); three or more authors (by year). Repeat the author's name for each reference. Give the names of all authors in the reference; never use "et al."

Use full names of journals, institutions, conferences, etc., except for extremely familiar abbreviations like "Dept." Remember that an abbreviation familiar to you may not be familiar to readers outside your field. If in doubt, write it out.

The reference list uses no quotation marks, italics, boldface, or underlining. Only the names of books and periodicals are in initial capitals. Names of papers, book chapters, pamphlets, and bulletins are not capitalized.

Citing references

Cite references in the text by last name and year, with chapter or page numbers if the reference is a book or lengthy report. For two authors, give both names. Do not use "et al." unless there are at least three authors.

Footnotes

AJAA does not use bibliographic or substantive footnotes. All bibliographic references should be at the end of the text. Instead of substantive footnotes, include the material in the main text or consider eliminating it.

Manuscript preparation

The entire manuscript, including abstract and references, should be typed on one side of standard-size paper, double spaced, with margins of at least one inch all around. Starting with the title page, label all pages in the upper righthand corner with the lead author's last name and the page number. Do not use hyphens unless the hyphen is part of the word.

Tables should fit on one page, be numbered consecutively with Arabic numerals, and be on a separate sheet. Every figure and table should be mentioned at least once in the text.

A detailed guide to formatting is availabie from the editor (address below).

Submission of manuscripts

Submit four high-quality copies to William Lockeretz, Editor, American Journal of Alternative Agriculture, School of Nutrition Science and Policy, Tufts University, Medford, MA 02155. The cover letter should state that the manuscript is an original contribution that has not been published elsewhere in substantially the same form, that it is not currently under consideration elsewhere, and that permission has been obtained for any copyrighted material used.

How you can help support the scientific and educational needs of a sustainable agricultural system

A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

Low-input alternative farming methods address these economic and environmental challenges. Alternative production systems point the way toward more profits, more individual choice, and long-term sustainability for our food system. More must be done to develop effective ways to make sure research, education, and information sources are readily available to farmers who want to adopt these techniques.

The Henry A. Wallace Institute for Alternative Agriculture needs your help in meeting this challenge. We are a nonprofit tax-exempt research and education organization established in 1983 to encourage and facilitate the adoption of low cost, resource conserving, and environmentally sound farming methods. We work directly with government agencies, colleges and universities, producer groups, and other institutions that provide research, education and information services to farmers.

The Wallace Institute also provides these services:

- *A resource to lawmakers and others who influence agricultural research, education, and information policy*
- *A voice for alternative agriculture in Washington*
- *A sponsor of research and education outreach programs*
- *A national clearinghouse for information on alternative agriculture*
- *A publisher of reliable scientific information on agricultural sustainability*

If you're interested in helping us, please contact the Henry A. Wallace Institute for Alternative Agriculture, 9200 Edmonston Road, Suite 117, Greenbelt, Maryland 20770-1551. The phone number is (301) 441-8777.

HENRY A. WALLACE INSTITUTE
FOR ALTERNATIVE AGRICULTURE